2200 General Library
Statistics/Engineering

GLBR 22A

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INTRODUCTION

Programs of varying complexity and from different fields have been included in this library to provide a sample of the usefulness and versatility of the 2200 series calculators. Programs have been selected bearing in mind their use and possible application. Each one contains a set of instructions which is easy to follow; at least one example per program has been given to facilitate checking and enhance comprehension.

In loading the program tapes advantage may be taken of SKIP and BACKSPACE features. These two features and their use are explained on a following page.

Programs are designed to display all output on the CRT. However, they may be adapted for printing the output on either the 2201 (typewriter) or the 2221 (Hi-Speed Printer).
NOTE: All operating instructions assume you are at the beginning of the block you desire.

If you wish to load programs that are separated by other blocks, you may use one of two methods.

(1) LOAD each block until you reach the desired block. This would require the repetition of 4 keystrokes for each block between your current position and your desired position. The 4 keystrokes would be:

CLEAR, CR/LF, LOAD, CR/LF

This method would require you to REWIND the tape if you desire a block which you have passed.

(2) Using the SKIP feature will allow you to go from one block to another with less work, and the BACKSPACE feature will allow you to "back-up" to a block that you have passed.

a) SKIP - Subtract from the Block # corresponding to where you wish to be, the Block # corresponding to your current location then subtract 1. This is the # of files to skip to place you at the beginning of the desired block.

For Example,

The last block loaded was 4; you wish to load Block 12.

\[ 12 - 4 - 1 = 7 \]

Key S, K, I, P, 7, F, CR/LF

b) BACKSPACE - Subtract from the block # corresponding to your present location, the block # corresponding to your desired location then add 1. This is the # of files to backspace to place you at the beginning of the desired block.

For Example,

The last block loaded was 12; you wish to load block 4,

\[ 12 - 4 + 1 = 9 \]

To change output device from 2216 (CRT display) to 2201 (typewriter) or 2221 (Hi-Speed Printer) the following procedure is used:

1. Choose what output is to be displayed or typed.

2. Insert a statement with the following information:
   For CRT display
   Statement # SELECT PRINT 005
   For Typewriter (2201)
   Statement # SELECT PRINT 211
   For Hi-Speed Printer (2221)
   Statement # SELECT PRINT 215

It may be advisable to change print to the CRT at the end of the program.
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<td></td>
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<td></td>
</tr>
<tr>
<td>7</td>
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<td></td>
</tr>
</tbody>
</table>
WANG
2200
SERIES
PROGRAM

LINEAR REGRESSION: Y = A + BX

TITLE

PS.01-2200.01A-00FI-1-0  6/1/73
NUMBER     DATE
2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT
Fits the curve Y = A + BX to a set of N data points by the method of least squares. Also, an analysis of regression is performed.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>1159</td>
</tr>
</tbody>
</table>

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PROGRAM DESCRIPTION

Fits the curve $Y = A + BX$ to a set of $N$ data points by the method of least squares. Also, an analysis of regression is performed - the regression table, $F$-value, coefficient of determination, coefficient of correlation, and standard error of estimate are printed out. The user may estimate values of $Y$ from the regression curve by inputing values of $X$.

Sample correlation coefficient, $r = \frac{n\Sigma XY - (\Sigma X)(\Sigma Y)}{\sqrt{[n\Sigma X^2 - (\Sigma X)^2][n\Sigma Y^2 - (\Sigma Y)^2]}}$

$B = \frac{n\Sigma XY - (\Sigma X)(\Sigma Y)}{n\Sigma X^2 - (\Sigma X)^2}$

$A = \frac{\Sigma Y - B\Sigma X}{n}$

Standard error of estimate, $s_{Y,X} = \frac{1}{n} \sqrt{\frac{n\Sigma Y^2 - (\Sigma Y)^2}{(n\Sigma XY - \Sigma X\Sigma Y)^2}}$

$F$-test for $r$, $F_r = \frac{r^2(n-2)}{1-r^2}$

Coefficient of Determination = $r^2$

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word **INSTRUCTION** will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right.
OPERATING INSTRUCTIONS

EXAMPLE

Perform a linear regression on the following data points

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td>14</td>
<td>9</td>
</tr>
</tbody>
</table>

1. Key **RESET**  **CLEAR**  **CR/LF**
   **LOAD**  **CR/LF**
2. Key **RUN**  **CR/LF**
3. **INSTRUCTION**
4. Key **# of Data Pairs**  **CR/LF**
5. **INSTRUCTION**
6. Key \(X_1 \rightarrow Y_1\) **CR/LF**
   Key \(X_2 \rightarrow Y_2\) **CR/LF**
   .
   Key \(X_n \rightarrow Y_n\) **CR/LF**
7. Read Answer
   0 DEG COEFF, is A
   1 DEG COEFF, is B

INPUT N
4. Key 8  **CR/LF**

INPUT DATA POINTS
6. Key 1 \(\rightarrow 1\)  **CR/LF**
   Key 3 \(\rightarrow 2\)  **CR/LF**
   .
   Key 1 \(\rightarrow 4 \rightarrow 9\)  **CR/LF**

Program will stop, the word STOP will appear on the CRT (display)
To have residual table, and other results outputted, Key **CONTINUE**  **CR/LF**

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OPERATING INSTRUCTIONS (Cont)

REGRESSION TABLE

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>SUM OF SQ.</th>
<th>DEG. FREEDOM</th>
<th>MEAN SQ.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REGRESSION</td>
<td>53.4545454545454</td>
<td>1</td>
<td>53.4545454545454</td>
</tr>
<tr>
<td>RESIDUAL</td>
<td>2.5454545454546</td>
<td>6</td>
<td>0.4242424242433</td>
</tr>
<tr>
<td>TOTAL</td>
<td>56</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

F = 125.9999999997

COEFF. OF DETERMINATION = .9545454545454
COEFF. OF CORRELATION = .97700842092
STANDARD ERROR OF ESTIMATE = .65133894728

8. **INSTRUCTION**

DO YOU WISH TO ESTIMATE VALUES OF Y FROM THE REGRESSION CURVE?
(1 = YES, 0 = NO)

9. Key either 1 or 0 **CR/LF**

If you choose 0 go to Step 15.

10. **INSTRUCTION**

INPUT X

11. Key X **CR/LF**

12. Read Y

Y = 3.727272727273

13. **INSTRUCTION**

ANOTHER POINT? (1 = YES, 0 = NO)


15. Program halts.

END PROGRAM

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6
WANG
2200
SERIES
PROGRAM

MULTIPLE LINEAR REGRESSION

TITLE

PS.01-2200.01A-00FI-2-0  6/1/73
NUMBER  DATE
2200A-01, 2215, 2216/2217

PROGRAM ABSTRACT

Fits the curve: \( Y = B_0 + B_1 X_1 + B_2 X_2 + \ldots + B_m X_m \)

to a set of \( N \) data points by the least squares method and then performs
an analysis of regression. This last part is optional.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td></td>
<td>2186</td>
</tr>
</tbody>
</table>
PROGRAM DESCRIPTION

This is a two-part program. The first segment fits the curve:

\[ y = b_0 + b_1 X_1 + b_2 X_2 + \ldots + b_M X_M \quad (M \leq 4) \]

to a set of \( N \) data points by the method of least squares. The second segment performs an analysis of regression - the regression table, F-value, coefficient of determination, coefficient of multiple correlation, and standard error of estimate are printed out. The user may also estimate values of \( Y \) from the regression curve by supplying values for the independent variables \( (X_1, X_2, \ldots, X_M) \).


Formulae

Solution matrix

\[ nb_0 + \sum_{i=1}^{N} X_i b_1 + \sum_{i=1}^{N} X_i^2 b_2 + \ldots + \sum_{i=1}^{N} X_i^M b_M = \Sigma Y \]

\[ \sum_{i=1}^{N} X_i b_0 + \sum_{i=1}^{N} X_i^2 b_1 + \sum_{i=1}^{N} X_i X_i b_2 + \ldots + \sum_{i=1}^{N} X_i X_i b_M = \Sigma X_i Y \]

\[ \vdots \]

\[ \sum_{i=1}^{N} X_i^2 b_0 + \sum_{i=1}^{N} X_i X_i b_1 + \sum_{i=1}^{N} X_i X_i b_2 + \ldots + \sum_{i=1}^{N} X_i^M b_M = \Sigma X_i^2 Y \]

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.
OPERATING INSTRUCTIONS

EXAMPLE

Given the following data

<table>
<thead>
<tr>
<th>Y</th>
<th>2</th>
<th>5</th>
<th>7</th>
<th>8</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>X₁</td>
<td>8</td>
<td>8</td>
<td>6</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>X₂</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

fit a regression equation of the form

\[ Y = b_0 + b_1 X_1 + b_2 X_2 \]

Calculate Y for X₁ = 2, X₂ = 4.

1. Key **RESET**  **CLEAR**  **CR/LF**
   **LOAD**  **CR/LF**

2. Key **RUN**  **CR/LF**

3. **INSTRUCTION**

4. Key # of Independent Variables  **CR/LF**
   # of Data Points,  **CR/LF**

5. **INSTRUCTION**

   Each data point \((X_1, X_2, \ldots, X_N, Y)\) is input in one line. Each element of the data point is separated from the others by a comma.

   For example,
   
   If \(M < 4\):
   
   Key \(X_1, X_2, Y\)  **CR/LF**  **CR/LF**
   
   If \(M = 4\):
   
   Key \(X_1, X_2, X_3, X_4, Y\)  **CR/LF**

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OPERATING INSTRUCTIONS (Cont)

6. Key \[ \frac{x_1}{1} \cdot x_2 \cdot \ldots \cdot x_M \cdot \frac{y}{Y} \]

or

Key \[ \frac{x_1}{1} \cdot x_2 \cdot x_3 \cdot x_4 \cdot \frac{y}{Y} \]

6. Key \[ 8 \cdot 0 \cdot 2 \] CR/LF CR/LF

7. INSTRUCTION

POINT 2

Continue as described in Step 6, until all data points have been entered.

8. Read Output

\[ B(0) = 4.488188976374 \]
\[ B(1) = -3.93700787E-02 \]
\[ B(2) = .6377952755911 \]

9. Program will STOP, to continue

Key CONTINUE CR/LF

10. Read Output

REGRESSION TABLE

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>SUM OF SQ.</th>
<th>DEG. FREEDOM</th>
<th>MEAN SQ.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REGRESSION</td>
<td>5.074015748031</td>
<td>2</td>
<td>2.537007874016</td>
</tr>
<tr>
<td>RESIDUAL</td>
<td>16.12598425197</td>
<td>2</td>
<td>8.062992125985</td>
</tr>
<tr>
<td>TOTAL</td>
<td>21.2</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

F= 2.146484375
COEFF. OF DETERMINATION= .2393403654732
COEFF. OF MULTIPLE CORRELATION= .48922424866
STANDARD ERROR OF ESTIMATE= 2.8395406101

DO YOU WISH TO ESTIMATE VALUES OF Y FROM THE REGRESSION CURVE? (1=YES, 0=NO)

COORDINATE X 1
COORDINATE X 2
Y = 6.96052921259
ANOTHER POINT?

11. INSTRUCTION

DO YOU WISH TO ESTIMATE VALUES OF Y FROM THE REGRESSION CURVE?
(1 = YES, 0 = NO)

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12. Key 1 or 0

If you keyed 0, then go to Step 19.

12. Key 1

13. INSTRUCTION

14. Key X1

15. INSTRUCTION

14. Key 2

15. Continue as in Step 14, until all coordinates have been entered.

16. Read Answer

17. INSTRUCTION

18. Go to Step 12.

19. Program Ends

Y = 6.96062992159

ANOTHER POINT?

END PROGRAM
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Nth ORDER REGRESSION

TITLE

PS. 01-2200. 01A-00FI-3-0  6/1/73
NUMBER  DATE
2200A-01, 2215, 2216/2217

PROGRAM ABSTRACT

Fits the curve:  \( Y = b_0 + b_1 X + b_2 X^2 + \ldots + b_m X^m \)

to a set of \( N(X, Y) \)- data points by the least squares method and then performs an analysis of regression. This last part is optional.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td></td>
<td>2233</td>
</tr>
</tbody>
</table>

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PROGRAM DESCRIPTION

This is a two-part program. The first segment fits the curve:

\[ Y = b_0 + b_1 X + b_2 X^2 + \ldots + b_M X^M \]

to a set of \( N(X, Y) \) data points by the method of least squares. The second segment performs an analysis of regression - the regression table, \( F \)-value, coefficient of determination, coefficient of correlation, and standard error of estimate are printed out. The user may also estimate values of \( Y \) from the regression curve by supplying values for \( x \). \((M \leq 6)\)


Formulae

\[ b_0, b_1, \ldots, b_M \] are the solutions of the following equations

\[ m b_0 + (\Sigma X)b_1 + \ldots + (\Sigma X^M)b_M = \Sigma Y \]
\[ (\Sigma X)b_0 + (\Sigma X^2)b_1 + \ldots + (\Sigma X^{M+1})b_M = \Sigma XY \]
\[ \vdots \]
\[ (\Sigma X^M)b_0 + (\Sigma X^{M+1})b_1 + \ldots + (\Sigma X^{2M})b_M = \Sigma X^M \]

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.
OPERATING INSTRUCTIONS

EXAMPLE

Given the following data

<table>
<thead>
<tr>
<th>X</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>9.1</td>
<td>7.3</td>
<td>3.2</td>
<td>4.6</td>
<td>4.8</td>
<td>2.9</td>
<td>5.7</td>
<td>7.1</td>
<td>8.8</td>
<td>10.2</td>
</tr>
</tbody>
</table>

fit the curve

\[ Y = b_0 + b_1 X + b_2 X^2 \]

and estimate \( Y \) at \( X = 2 \).

1. Key **RESET**  **CLEAR**  **CR/LF**
   **LOAD**  **CR/LF**

2. Key **RUN**  **CR/LF**

3. **INSTRUCTION**

4. Key **M \times N**  **CR/LF**

5. **INSTRUCTION**

**INPUT DATA POINTS**

NOTE: 0 raised to the 0 power will result in an error, therefore if \( X = 0 \) use \( X = .0000001 \) or even some other very small # to approximate 0.

6. Key \( X_1 \div Y_1 \)  **CR/LF**
   Key \( X_2 \div Y_2 \)  **CR/LF**
   .
   Key \( X_N \div Y_N \)  **CR/LF**

7. Key \( - \)  **0**  **0**  **0**  **0**  **1**  **9**  **1**  **CR/LF**
   Key \( 1 \div 7 \)  **3**  **CR/LF**
   Key \( 2 \div 3 \)  **2**  **CR/LF**
   Key \( 3 \div 4 \)  **6**  **CR/LF**
   .
   Key \( 9 \div 1 \)  **0**  **2**  **CR/LF**

7. Read Output

0 DEG. COEFF. = \( b_0 \)

1 DEG. COEFF. = \( b_1 \)

. .

M DEG. COEFF. = \( b_M \)

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OPERATING INSTRUCTIONS (Cont)

8. Program halts, to continue, Key
   CONTINUE  CR/LF

9. Read Output

   REGRESSION TABLE
   SOURCE    SUM OF SQ.    DEG. FREEDOM    MEAN SQ.
   REGRESSION  48.92633145245    2    24.46316572623
   RESIDUAL    8.63466854755    7    1.233524078221
   TOTAL        57.561    9
   F= 19.8319320702
   COEFF. OF DETERMINATION= .8499989913388
   COEFF. OF CORRELATION= .92194956808
   STANDARD ERROR OF ESTIMATE= 1.1106412914
   DO YOU WISH TO ESTIMATE VALUES OF Y FROM
   THE REGRESSION CURVE? (1=YES, 0=NO)
   INPUT X
   Y= 5.168485296849
   ANOTHER POINT? (1=YES, 0=NO)

10. INSTRUCTION

11. Key 1 or 0  CR/LF
    If you Key 0, go to Step 17.

12. INSTRUCTION

13. Key X  CR/LF

14. Read Answer

15. INSTRUCTION

16. Go to Step 11.

17. Program halts.

DO YOU WISH TO ESTIMATE VALUES OF Y
FROM THE REGRESSION CURVE? (1=YES,
0=NO)

11. Key 1  CR/LF

13. Key 2  CR/LF

 INPUT X

Y = 5.168484893319

ANOTHER POINT? (1=YES, 0=NO)
WANG
2200
SERIES
PROGRAM

EXPOENENTIAL REGRESSION: \( Y = Ae^{BX} \)

TITLE

PS.01-2200.01A-00FI-4-0  6/4/73
NUMBER
DATE
2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT
Fits the curve: \( Y = Ae^{BX} \) to a set of \( N(X,Y) \) - data points by the least squares method and then performs an analysis of regression. This last part is optional.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td></td>
<td>1147</td>
</tr>
</tbody>
</table>
PROGRAM DESCRIPTION

Fits the curve:

\[ Y = Ae^{BX} \]

to a set of \( N \) data points, \((X_1, Y_1), (X_2, Y_2), \ldots, (X_N, Y_N)\).

The problem is reduced to linear regression by taking the log of both sides of equation (1):

\[ \log(Y) = \log(A) + BX \]

and substituting \( Y' = \log(Y) \) and \( A' = \log(A) \):

\[ Y' = A' + BX \]

A linear regression (by the method of least squares) is performed to determine \( A' \) and \( B \). Then, \( A \) is determined by:

\[ A = e^{A'} \]

An analysis of regression is done on the linear regression - the regression table, \( F \)-value, coefficient of determination, coefficient of correlation, and standard error of estimate are printed out. The user may estimate values of \( Y \) from the exponential regression curve by inputing values of \( X \).


Formulæ

\[ B = \frac{n \sum (X_i \log Y_i) - (\sum X_i) \left( \sum \log Y_i \right)}{n \sum X_i^2 - (\sum X_i)^2} \]

\[ A = \exp \left[ \frac{1}{n} \left\{ \left( \sum \frac{\log Y_i}{e_i} \right) - b \left( \sum X_i \right) \right\} \right] \]

\[ r = \frac{n \sum (X_i \log Y_i) - (\sum X_i) \left( \sum \log Y_i \right)}{\sqrt{\left\{ n \sum X_i^2 - (\sum X_i)^2 \right\} \left\{ n \sum \left( \frac{\log Y_i}{e_i} \right)^2 - (\sum \log Y_i)^2 \right\}}} \]
PROGRAM DESCRIPTION (Cont)

F-Test for r, \( F = \frac{r^2(n-2)}{1-r^2} \)

Coefficient of Determination = \( r^2 \)

Standard error of estimate, \( \hat{S}_{Y\cdot X} = \frac{1}{N} \sqrt{\frac{(n\Sigma(\text{LOG}Y)^2 - (\Sigma \text{LOG} Y)^2)^2}{n\Sigma X^2 - (\Sigma X)^2} - \frac{(n\Sigma X(\text{LOG}Y) - \Sigma X\Sigma \text{LOG}Y)^2}{n\Sigma X^2 - (\Sigma X)^2}} \)

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.
OPERATING INSTRUCTIONS

EXAMPLE

Given the following data

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>.25</td>
</tr>
<tr>
<td>1</td>
<td>1.1</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>22.5</td>
</tr>
<tr>
<td>4</td>
<td>101</td>
</tr>
<tr>
<td>5</td>
<td>452</td>
</tr>
</tbody>
</table>

fit $Y = Ae^{BX}$ and estimate $Y$ at $X = 7$.

1. Key **RESET**  **CLEAR**  **CR/LF**
   **LOAD**  **CR/LF**
2. Key **RUN**  **CR/LF**
3. **INSTRUCTION**
4. Key # of data points  **CR/LF**
5. **INSTRUCTION**
6. Key $X_1 \rightarrow Y_1$  **CR/LF**
   Key $X_2 \rightarrow Y_2$  **CR/LF**
   ... 
   Key $X_N \rightarrow Y_N$  **CR/LF**
7. Read Output
8. Program Halts. To continue,
   Key **CONTINUE**  **CR/LF**

INPUT N
4. Key 6  **CR/LF**

INPUT DATA POINTS
6. Key 0  .  2  5  **CR/LF**
   Key 1  .  1  .  1  **CR/LF**
   ... 
   Key 5  .  4  5  2  **CR/LF**

$A = .247981950976$
$B = 1.501811174648$

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9. **Read Output**

**REGRESSION TABLE**

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>SUM OF SQ.</th>
<th>DEG. FREEDOM</th>
<th>MEAN SQ.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REGRESSION</td>
<td>39.47014407519</td>
<td>1</td>
<td>39.47014407519</td>
</tr>
<tr>
<td>RESIDUAL</td>
<td>2.24468250E-04</td>
<td>4</td>
<td>5.61170625E-05</td>
</tr>
<tr>
<td>TOTAL</td>
<td>39.47036854344</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

\[ F = 703353.7094924 \]

COEFF. OF DETERMINATION = .9999943129933
COEFF. OF CORRELATION = .9999971565

STANDARD ERROR OF ESTIMATE = 7.49113225E-03

DO YOU WISH TO ESTIMATE VALUES OF Y FROM THE REGRESSION CURVE? (1=YES, 0=NO)

INPUT X

\[ Y = 9120.490903452 \]

ANOTHER POINT? (1=YES, 0=NO)

10. **INSTRUCTION**

DO YOU WISH TO ESTIMATE VALUES OF Y FROM THE REGRESSION CURVE? (1=YES, 0=NO)

11. **INSTRUCTION**

   Key 1 or 0 **CR/LF**

   If you key 0, go to Step 17.

11. **INSTRUCTION**

   Key 1 **CR/LF**

12. **INSTRUCTION**

   INPUT X

13. **INSTRUCTION**

   Key X **CR/LF**

14. **Read Answer**

15. **INSTRUCTION**

   ANOTHER POINT? (1=YES, 0=NO)

16. **Go to Step 11.**

17. **Program halts**

   END PROGRAM

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GEOMETRIC REGRESSION: $Y = AX^B$

### PROGRAM ABSTRACT

Fits the curve $Y = AX^B$ to a set of $N$ data points, 

$(X_1, Y_1), (X_2, Y_2), \ldots, (X_N, Y_N)$.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td></td>
<td>1155</td>
</tr>
</tbody>
</table>

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PROGRAM DESCRIPTION

Fits the curve:

\[ Y = AX^B \]

(1) to a set of N data points, \((X_1, Y_1), (X_2, Y_2), \ldots, (X_N, Y_N)\).

The problem is reduced to linear regression by taking the log of both sides of equation (1):

\[ \log(Y) = \log(A) + B \log(X) \]

and substituting \(Y' = \log(Y), X' = \log(X),\) and \(A' = \log(A)\):

(2) \[ Y' = A' + BX' \]

A linear regression (by the method of least squares) is performed to determine \(A'\) and \(B\). Then, \(A\) is determined by:

\[ A = e^{A'} \]

An analysis of regression is done on the linear regression - the regression table, F-value, coefficient of determination, coefficient of correlation, and standard error of estimate are printed out. The user may also estimate values of \(Y\) from the geometric regression curve by inputting values of \(X\).


Formulae

\[
B = \frac{n \sum_{i=1}^{e_1} \frac{\log X_i \log Y_i}{e_1} - (\sum_{i=1}^{e_1} \log X_i)(\sum_{i=1}^{e_1} \log Y_i)}{n \sum_{i=1}^{e_1} \left( \frac{\log X_i}{e_1} \right)^2 - (\sum_{i=1}^{e_1} \frac{\log X_i}{e_1})^2}
\]

\[
A = \exp \left[ \frac{1}{n} \left\{ \sum_{i=1}^{e_1} \left( \frac{\log Y_i}{e_1} \right) - (2 \sum_{i=1}^{e_1} \frac{\log X_i}{e_1})b \right\} \right]
\]

\[
r = \frac{n \sum_{i=1}^{e_1} \frac{\log X_i \log Y_i}{e_1} - (\sum_{i=1}^{e_1} \log X_i)(\sum_{i=1}^{e_1} \log Y_i)}{\sqrt{n \sum_{i=1}^{e_1} \left( \frac{\log X_i}{e_1} \right)^2 - (\sum_{i=1}^{e_1} \frac{\log X_i}{e_1})^2 \cdot n \sum_{i=1}^{e_1} \left( \frac{\log Y_i}{e_1} \right)^2 - (\sum_{i=1}^{e_1} \frac{\log Y_i}{e_1})^2}}
\]
Standard Error of Estimate $\hat{S}_{Y\cdot X}$

$$\frac{1}{n} \sqrt{n \Sigma (\log Y)^2 - (\Sigma \log Y)^2} - \frac{n \Sigma (\log X) (\log Y) - \Sigma \log Y \Sigma \log X}{n \Sigma (\log X)^2 - (\Sigma \log X)^2}$$

F test for $r$, $F_r = \frac{r^2 (n-2)}{1 - r^2}$

Coeff. of determination $= r^2$

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right.
OPERATING INSTRUCTIONS

EXAMPLE

Given the following data

<table>
<thead>
<tr>
<th>X</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>.5</td>
<td>2</td>
<td>5</td>
<td>8</td>
<td>12</td>
<td>18</td>
<td>25</td>
<td>32</td>
</tr>
</tbody>
</table>

fit \( Y = AX^B \) and estimate \( Y \) when \( X = 2.5 \).

1. Key **RESET** CR/LF
2. Key **CLEAR** CR/LF
3. Key **LOAD** CR/LF
4. Key **RUN** CR/LF

5. INSTRUCTION

INPUT N

6. Key \( X_1 \) - \( Y_1 \) CR/LF
   Key \( X_2 \) - \( Y_2 \) CR/LF
   .
   .
   Key \( X_N \) - \( Y_N \) CR/LF

7. Read output

   \[ A = 0.5097863625245 \]
   \[ B = 1.993368171127 \]

8. Program halts. To continue

   Key **CONTINUE** CR/LF

Since \( \log(0) \) is undefined, you must approximate 0 by a near zero value, such as \( 0.0000001 \).
OPERATING INSTRUCTIONS (Cont)

9. Read Output

REGRESSION TABLE

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>SUM OF SQ.</th>
<th>DEG. FREEDOM</th>
<th>MEAN SQ.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REGR.</td>
<td>13.7616770110</td>
<td>1</td>
<td>13.7616770110</td>
</tr>
<tr>
<td>RESIDUAL</td>
<td>1.21254695E-02</td>
<td>6</td>
<td>2.02091158E-03</td>
</tr>
<tr>
<td>TOTAL</td>
<td>13.77380248054</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

F= 6809.63832879
COEFF. OF DETERMINATION= .999196715978
COEFF. OF CORRELATION= .99955973888

STANDARD ERROR OF ESTIMATE= 4.49545502E-02

DO YOU WISH TO ESTIMATE VALUES OF Y FROM THE REGRESSION CURVE? (1=YES, 0=NO)

INPUT X

Y = 3.166862158769

ANOTHER POINT? (1=YES, 0=NO)

10. INSTRUCTION

DO YOU WISH TO ESTIMATE VALUES OF Y FROM THE REGRESSION CURVE?
(1 = YES, 0 = NO)

11. Key 1 or 0  CR/LF

If you key 0, go to Step 17.

12. INSTRUCTION

13. Key X  CR/LF

INPUT X

13. Key 2 . 5  CR/LF

14. Read Answer

Y = 3.166862158769

15. INSTRUCTION

ANOTHER POINT? (1 = YES, 0 = NO)

16. Go to Step 11.

17. Program halts.

END PROGRAM

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LINEAR CORRELATION

TITLE

PS.01-2200.01A-00F1-6-0 6/1/73
NUMBER DATE
2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT

Computes the coefficient of linear correlation, R, between 2 variables, X and Y.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td></td>
<td>454</td>
</tr>
</tbody>
</table>

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PROGRAM DESCRIPTION

Computes the coefficient of linear correlation, R, between 2 variables, X and Y, by the equation:

\[
R = \frac{N\Sigma (X_iY_i) - (\Sigma X_i)(\Sigma Y_i)}{\sqrt{(N\Sigma X_i^2 - (\Sigma X_i)^2)(N\Sigma Y_i^2 - (\Sigma Y_i)^2)}}
\]

where

\(N\) = number of observations

\((X_1, X_2), \ldots, (X_N, Y_N)\) are the data points.

The degree of linear correlation varies from no linear correlation \((R = 0)\) to perfect linear correlation \((R = \pm 1)\).

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.
OPERATING INSTRUCTIONS

EXAMPLE

Given the following data

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>.25</td>
</tr>
<tr>
<td>1</td>
<td>1.1</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>22.5</td>
</tr>
<tr>
<td>4</td>
<td>101</td>
</tr>
<tr>
<td>5</td>
<td>452</td>
</tr>
</tbody>
</table>

determine the coeff. of correlation.

1. Key **RESET** CLEAR CR/LF
   LOAD CR/LF
2. Key **RUN** CR/LF
3. **INSTRUCTION**
4. Key # of data points CR/LF
5. **INSTRUCTION**

6. Key X₁ Y₁ CR/LF
   Key X₂ Y₂ CR/LF
   ... CR/LF
   Key Xₙ Yₙ CR/LF
7. Read Answer

   NO. OF DATA POINTS, N?
   4. Key 6 CR/LF
   INPUT DATA POINTS 1/LINE (Xᵢ, Yᵢ, CARRIAGE RETURN)
   6. Key 0 . . . 2 5 CR/LF
      Key 1 . 1 . 1 CR/LF
      .
      Key 5 . 4 5 2 CR/LF
   COEFF. OF CORRELATION = .7730712833711

END PROGRAM

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WANG
2200
SERIES
PROGRAM

CORRELATION MATRIX

TITLE

PS.01-2200.01A-00F1-7-0  6/1/73
NUMBER       DATE
2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT

Given a set of N observations in M variables, the correlation
coefficient between each pair of variables is computed.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td></td>
<td>1596</td>
</tr>
</tbody>
</table>
PROGRAM DESCRIPTION

Given a set of N observations in M variables, the correlation coefficient between each pair of variables is computed. The observations should be arranged in the following format: (M ≤ 9)

\[
\begin{array}{cccc}
V_1 & V_2 & V_3 & \cdots & V_M \\
1 & 1.2 & 1.4 & & \\
2 & 3.0 & 3.6 & & \\
3 & & & & \\
& & & & \\
& & & & \\
& & & & \\
N & & & & \\
\end{array}
\]

The correlation matrix is an array of correlation coefficients where the element in the ith row and jth column of the matrix is the correlation coefficient between the ith and jth variables. The correlation matrix is printed out row by row skipping a line between each row; each row is printed out from left to right using as many lines as required.


Formula

\[
r = \frac{N \sum_{I,J} X_I X_J - \sum_I X_I \sum_J X_J}{\sqrt{(N \sum_I X_I^2 - (\sum_I X_I)^2)(N \sum_J X_J^2 - (\sum_J X_J)^2)}}
\]

r is the coefficient of correlation between Col. I and Row J.

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right.
1. Key **RESET**  **CLEAR**  **CR/LF**
   **LOAD**  **CR/LF**

2. Key **RUN**  **CR/LF**

3. **INSTRUCTION**

4. Key # of OBS.  **# of Variables,**  **CR/LF**

5. **INSTRUCTION**

   The matrix is inputted 1 row at a time, each element of a row being separated from the other by a comma. The end of a row is signaled by a **CR/LF** immediately following a ?.

   For example, a row (1, 2, 3, 4, 5) would be inputted as follows:

   :1, 2, 3, 4, 5 **CR/LF**
   ? **CR/LF**

6. Key Row 1 (separate each element by a comma)  **CR/LF**

7. Continue as in Step 6 until all rows have been entered.
8. Read Output

**CORRELATION MATRIX:**

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>0.95803840329759</th>
<th>0.98894772873546</th>
<th>0.78616543244404</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.95803840329759</td>
<td>1</td>
<td>0.99794032635592</td>
<td>0.97367352937951</td>
<td></td>
</tr>
<tr>
<td>0.98894772873546</td>
<td>0.99794032635592</td>
<td>1</td>
<td>0.91538497613811</td>
<td></td>
</tr>
<tr>
<td>0.78616543244404</td>
<td>0.97367352937951</td>
<td>0.91538497613811</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>0.95803840329759</td>
<td>0.99794032635592</td>
<td>0.92563854637324</td>
<td>0.99649291921381</td>
<td></td>
</tr>
<tr>
<td>0.98894772873546</td>
<td>0.97367352937951</td>
<td>0.92563854637324</td>
<td>0.99649291921381</td>
<td></td>
</tr>
<tr>
<td>0.78616543244404</td>
<td>0.91538497613811</td>
<td>0.99649291921381</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>
## VARIANCE ANALYSIS

<table>
<thead>
<tr>
<th>BLOCK NO.</th>
<th>PROGRAM TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>ONE-WAY ANALYSIS OF VARIANCE</td>
</tr>
<tr>
<td>9</td>
<td>TWO-WAY ANALYSIS OF VARIANCE</td>
</tr>
<tr>
<td>10</td>
<td>ANALYSIS OF VARIANCE - LATIN SQUARES</td>
</tr>
</tbody>
</table>
This page intentionally left blank
ONE-WAY ANALYSIS OF VARIANCE

TITLE

PS.01-2200.01A-00FI-8-0  6/1/73
NUMBER DATE
2200A-01, 2215, 2216, 2217
EQUIPMENT

PROGRAM ABSTRACT

Performs a one-way analysis of variance on up to 99 groups of data.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td></td>
<td>1565</td>
</tr>
</tbody>
</table>
PROGRAM DESCRIPTION

Performs a 1-way analysis of variance on up to 99 groups of data. The analysis of variance table and F-value are printed out.


Formulae

Suppose that we have independent random samples of sizes \( n_1, n_2, \ldots, n_k \), from \( k \) populations and \( X_{ij} \) is the \( j \)th observation of \( i \)th population with

\[
n_1 + n_2 + \ldots + n_k = n.
\]

Suppose that \( X_{ij} \) are independently \( N(\mu_i, \sigma^2) \), \( i=1, \ldots, k \). and \( X_{ij} = \mu_i + e_{ij} \)

\[ (i=1, \ldots,k; j=1, \ldots,n_i) \]

\( e_{ij} \) are independently \( N(0, \sigma^2) \)

Then the F-test for the null-hypothesis,

\[
H_0 : \mu_1 = \mu_2 = \ldots = \mu_k
\]

can be written as:

\[
F = \frac{SSB/k-1}{SSE/n-k} = \frac{A}{B} = \frac{n-k}{k-1}
\]

\[
\left[ \frac{1}{k} \left( \frac{\sum_{i=1}^{k} \frac{n_i}{n} (\sum_{j=1}^{n_i} X_{ij})^2}{\sum_{i=1}^{k} \frac{n_i}{n} \left( \sum_{j=1}^{n_i} X_{ij} \right)^2} \right) \right] - \frac{1}{n} \left( \frac{\sum_{i=1}^{k} \frac{n_i}{n} \sum_{j=1}^{n_i} X_{ij}}{\sum_{i=1}^{k} \frac{n_i}{n} \left( \sum_{j=1}^{n_i} X_{ij} \right)} \right)^2
\]

with \( k-1 \) and \( n-k \) degrees of freedom.

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.
OPERATING INSTRUCTIONS

EXAMPLE

Given the following data, perform a 1-way analysis of variance

<table>
<thead>
<tr>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

1. Key **RESET**  **CLEAR**  **CR/LF**
   **LOAD**  **CR/LF**

2. Key **RUN**  **CR/LF**

3. **INSTRUCTION**

4. Key # of Groups  **CR/LF**

5. **INSTRUCTION**

6. Key # of Elements in Group 1  **CR/LF**

7. **INSTRUCTION**

Input the elements in the group when requested. The elements in the group are inputted 4/line. If necessary, add zeroes to the end of the group to complete the set of 4 elements. For example, the group 1, 2, 3, 4, 5, 6 is inputted in 2 steps as follows:

: 1, 2, 3, 4
: 5, 6, 0, 0

Note: Each element is separated by a comma.
8. Key Group 1, 4/line CR/LF

Continue until entire group has been entered.

9. Program will back to Step 5.
The next group is asked for. This loop will continue until all groups have been entered.

10. Read Variance Table and F-value.

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>SUM OF SQ.</th>
<th>DEG. FREEDOM</th>
<th>MEAN SQ.</th>
</tr>
</thead>
<tbody>
<tr>
<td>BETW. GROUPS</td>
<td>.4318181818</td>
<td>2</td>
<td>.2159090909</td>
</tr>
<tr>
<td>WITHIN GROUPS</td>
<td>11.75</td>
<td>8</td>
<td>1.46875</td>
</tr>
<tr>
<td>TOTAL</td>
<td>12.18181818</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>F= .1470019342298</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

11. Program Ends END PROGRAM
WANG
2200
SERIES
PROGRAM

TWO-WAY ANALYSIS OF VARIANCE

TITLE

PS. 01-2200.01A-00FI-9-0  6/1/73
NUMBER  DATE
2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT
Computes the analysis of variance table and the F-value for the row and column variance in a two-factor experiment.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td></td>
<td>1652</td>
</tr>
</tbody>
</table>
PROGRAM DESCRIPTION

Computes the analysis of variance table and the $F$-values for the row and column variance in a two-factor experiment.


Formulae:

The analysis of variance table for the observations:

\[ X_{ij} \quad [i = 1, 2, \ldots, k; \quad j = 1, 2, \ldots, n] \]

where $k =$ number of rows and $n =$ number of columns is given below:

\[
\begin{align*}
X_{1.} &= \frac{1}{n} \sum_{j=1}^{n} X_{ij}, \\
X_{.j} &= \frac{1}{k} \sum_{i=1}^{k} X_{ij}, \text{ and } X_{..} = \frac{1}{nk} \sum_{i} \sum_{j} X_{ij};
\end{align*}
\]

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>Degrees of Freedom</th>
<th>Mean Square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Rows</td>
<td>$SS_A = n \sum_{i} (X_{i.} - X_{..})^2$</td>
<td>$k-1$</td>
<td>$A = \frac{SS_A}{k-1}$</td>
<td>$F_A = \frac{A}{C}$</td>
</tr>
<tr>
<td>Between columns</td>
<td>$SS_B = k \sum_{j} (X_{.j} - X_{..})^2$</td>
<td>$n-1$</td>
<td>$B = \frac{SS_B}{n-1}$</td>
<td>$F_B = \frac{B}{C}$</td>
</tr>
<tr>
<td>Residual</td>
<td>$SS_e = \sum_{i} \sum_{j} (X_{ij} - X_{i.} - X_{.j} + X_{..})^2$</td>
<td>$(k-1)(n-1)$</td>
<td>$C = \frac{SS_e}{(k-1)(n-1)}$</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>$SS_t = \sum_{i} \sum_{j} (X_{ij} - X_{..})^2$</td>
<td>$nk-1$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.
OPERATING INSTRUCTIONS

1. Key **RESET**  **CLEAR**  **CR/LF**
   **LOAD**  **CR/LF**

2. Key **RUN**  **CR/LF**

3. **INSTRUCTION**

4. Key # of rows  # of cols.
   **CR/LF**

5. **INSTRUCTION**

   NO. OF ROWS, NO. OF COLUMNS?

   ?

   4. Key 6  4  **CR/LF**

   INPUT TABLE OF DATA

   It is assumed that the data is arranged in a table (see example). The
data in the table is imputed, row by row, 4 elements/line. If necessary,
attach zeroes to the end of each row to complete the set of 4 input elements.
For example, the row 1, 2, 3, 4, 5 would be imputed in 2 steps as follows:

   : 1, 2, 3, 4
   : 5, 0, 0, 0

6. Key Row 1  **CR/LF**

6. Key 2  7  8  2  7  3  2  8  5  **CR/LF**

   , 3  8  5  **CR/LF**

7. Continue entering rows until
all rows have been entered.

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8. Read Variance Table and F-value.

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>SUM OF SQ.</th>
<th>DEG. FREEDOM</th>
<th>MEAN SQ.</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL</td>
<td>137492.958333</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>COLUMN</td>
<td>16735.791666</td>
<td>3</td>
<td>5578.597222</td>
</tr>
<tr>
<td>ROW</td>
<td>106275.208333</td>
<td>5</td>
<td>21255.041666</td>
</tr>
<tr>
<td>RESIDUAL</td>
<td>14481.958333</td>
<td>15</td>
<td>965.4638889333</td>
</tr>
</tbody>
</table>

F(COL) = 5.779152125569
F(ROW) = 22.01536682028

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ANALYSIS OF VARIANCE - LATIN SQUARES

TITLE

PS. 01-2200.01A-00F1-10-0 6/1/73

NUMBER  DATE
2200A-01, 2215, 2216/2217

EQUIPMENT

PROGRAM ABSTRACT

Computes the analysis of variance table and the F-value for column, row and treatment variance for a simple Latin Square design.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td></td>
<td>1184</td>
</tr>
</tbody>
</table>

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PROGRAM DESCRIPTION

Computes the analysis of variance table and the F-values for column, row, and treatment variance for a simple Latin square design. The user must supply the matrix of treatment assignments and the matrix of data.


Formulae

The program requires that the matrix of treatment assignments be defined by data statements.

We shall denote the observations by \( \{ X_{ijk} \} \), where \( X_{ijk} \) is the observation on the treatment combination where factor A is at the ith level, B at the jth, C at the kth and the triples (i, j, k) take on only the \( m^2 \) values dictated by the particular Latin Square selected for the experiment. Then \( \{ X_{ijk} \} \) can be tabulated in the following fashion.

\[
\begin{array}{cccc}
1 & 2 & 3 & \ldots & j=m \\
1 & X_{111} & X_{122} & X_{133} & \ldots & X_{1mm} \\
2 & X_{212} & X_{223} & X_{234} & \ldots & X_{2m1} \\
\vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\
i=m & X_{m1m} & X_{m21} & X_{m32} & \ldots & X_{mm(m-1)} \\
\end{array}
\]

Let

\[
\bar{X}_{..} = \frac{1}{m} \sum_{j,k} X_{ijk} , \quad \bar{X}_{.j} = \frac{1}{m} \sum_{i,k} X_{ijk}
\]

\[
\bar{X}_{..k} = \frac{1}{m} \sum_{i,j} X_{ijk} , \quad \bar{X} = \frac{1}{m^2} \sum_{ijk} X_{ijk}
\]
Note that there are only $m$ terms in the sum $\sum_{j,k} X_{ijk}$, for there are only $m$ pairs $(j,k)$ corresponding to a fixed $i$.

Then,

$SS_A = m \sum_i (\bar{X}_{i..} - \bar{X})^2$, $SS_B = m \sum_j (\bar{X}_{.j} - \bar{X})^2$

$SS_C = m \sum (\bar{X}_{..k} - \bar{X})^2$, $SS_{C} = \sum_{i,j,k} (X_{ijk} - \bar{X}_{i..} - \bar{X}_{.j} - \bar{X}_{..k} + 2\bar{X})^2$

$SS_t = \sum_{i,j,k} (X_{ijk} - \bar{X})^2$

Let $A = SS_A / (m-1)$, $B = SS_B / (m-1)$, $C = SS_C / (m-1)$, $E = SS_C / ((m-1)(m-2))$.

Then, the analysis of variance table can be presented in the following fashion:

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Sum of Squares</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Row</td>
<td>$m-1$</td>
<td>$SS_A$</td>
<td>A</td>
<td>$F_A = \frac{A}{E}$</td>
</tr>
<tr>
<td>Column</td>
<td>$m-1$</td>
<td>$SS_B$</td>
<td>B</td>
<td>$F_B = \frac{B}{E}$</td>
</tr>
<tr>
<td>Treatment</td>
<td>$m-1$</td>
<td>$SS_C$</td>
<td>C</td>
<td>$F_C = \frac{C}{E}$</td>
</tr>
<tr>
<td>Residual</td>
<td>$(m-1)(m-2)$</td>
<td>$SS_e$</td>
<td>E</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>$m^2 - 1$</td>
<td>$SS_t$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NOTE**

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word **INSTRUCTION** will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.
OPERATING INSTRUCTIONS

EXAMPLE

Matrix of treatment assignments:

\[
\begin{pmatrix}
1 & 2 & 3 & 4 & 5 \\
2 & 3 & 4 & 5 & 1 \\
3 & 4 & 5 & 1 & 2 \\
4 & 5 & 1 & 2 & 3 \\
5 & 1 & 2 & 3 & 4
\end{pmatrix}
\]

Matrix of data:

\[
\begin{pmatrix}
40 & 50 & 30 & 40 & 40 \\
50 & 55 & 35 & 50 & 55 \\
40 & 60 & 40 & 50 & 45 \\
35 & 40 & 30 & 35 & 30 \\
55 & 60 & 45 & 45 & 60
\end{pmatrix}
\]

1. Key **RESET**  CLEAR  CR/LF

    LOAD  CR/LF

Enter N in data statement 500. Enter the matrix of treatment assignments row by row in data statements 501 to 998. For example, one might have for a 5 x 5 Latin Square: \(N \leq 9\)

500 DATA 5
501 DATA 1, 2, 3, 4, 5
502 DATA 2, 3, 4, 5, 1
503 DATA 3, 4, 5, 1, 2
504 DATA 4, 5, 1, 2, 3
505 DATA 5, 1, 2, 3, 4

Note: Please separate matrix elements with commas and no spaces.

2. Key 5 0 0  DATA  N

3. Key 5 0 1  DATA  A_{1,1}

   A_{1,2} \ldots A_{1,N}  CR/LF

   \vdots

   Key 5 0  N  DATA  A_{N,1}

   A_{N,2} \ldots A_{N,N}  CR/LF

2. Key 5 0 0  DATA  5

3. Key 5 0 1  DATA  1 2 3

   \vdots

   Key 5 0 5  DATA  5 1 2

   3 4  CR/LF

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50
OPERATING INSTRUCTIONS (Cont)

4. Key **RUN** **CR/LF**

5. **INSTRUCTION**

**INPUT TABLE OF DATA**

The matrix of data is entered 1 row at a time. The elements of the row are separated by a comma. The end of a row is signaled by **CR/LF**. For example, row 1 is 1, 2, 3, 4, 5, 6 and is entered as follows:

```
1, 2, 3, 4, 5, 6, **CR/LF**
? **CR/LF**
```

6. Key **Row 1 of data matrix,** **CR/LF** **CR/LF**

6. Key **4 0 5 0 3 0 4 0**

7. Continue until all rows have been entered.

8. Read Variance Table and F-values.

```
SOURCE    SUM OF SQ.   DEG. FREEDOM   MEAN SQ.
ROW       1146         4             286.5
COLUMN    736          4             184
TREATMENT 146          4             36.5
RESIDUAL  168          12            14
TOTAL     2196         24

F(ROW) = 20.46420571429
F(COL) = 12.14285714286
F(TREAT) = 2.607142857143
```
This page intentionally left blank
<table>
<thead>
<tr>
<th>BLOCK NO.</th>
<th>PROGRAM TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>CHI-SQUARE TEST &amp; DISTRIBUTION</td>
</tr>
<tr>
<td>12</td>
<td>CHI-SQUARE ANALYSIS</td>
</tr>
<tr>
<td>13</td>
<td>T-TEST</td>
</tr>
<tr>
<td>14</td>
<td>WILCOXON MATCHED - PAIRS SIGNED - RANKS TEST</td>
</tr>
<tr>
<td>15</td>
<td>MANN-WHITNEY U-TEST</td>
</tr>
</tbody>
</table>
WANG
2200
SERIES
PROGRAM

CHI-SQUARE TEST & DISTRIBUTION

TITLE

PS.01-2200.01A-00FI-11-0  6/1/73
NUMBER  DATE
2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT

The Chi-Square test compares an observed distribution with an assumed distribution.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td></td>
<td>891</td>
</tr>
</tbody>
</table>
PROGRAM DESCRIPTION

The Chi-Square ($X^2$) test compares an observed distribution with an assumed distribution.

$$X^2 = \sum_{i=1}^{N} \frac{(O_i - E_i)^2}{E_i}$$

where:

$O_i =$ observed frequency

$E_i =$ expected frequency

$N =$ number of observed values

The larger the deviations, the larger the value of $X^2$.

The Chi-Square distribution is a continuous distribution used primarily to check the "goodness of fit" of an assumed distribution when compared to observed frequencies. If $V =$ degrees of freedom, the probability integral may be approximated by:

$V$ odd: $P(X^2, V) = \left(\frac{(X^2)^2}{V(V-2) \cdots 1}\right) \left(\frac{2}{X^2}\right)^{\frac{1}{2}} \left(1 + \sum_{R=1}^{\infty} \frac{(X^2)^R}{(V+2) \cdots (V+2R)}\right)$

$V$ even: $P(X^2, V) = \left(\frac{(X^2)^2}{V(V-2) \cdots 2}\right) \left(\frac{2}{X^2}\right)^{\frac{1}{2}} \left(1 + \sum_{R=1}^{\infty} \frac{(X^2)^R}{(V+2) \cdots (V+2R)}\right)$

Precision should be to about $10^{-5}$.

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right.
OPERATING INSTRUCTIONS

1. Key **RESET**  **CLEAR**  **CR/LF**  
   **LOAD**  **CR/LF**

2. Key **RUN**  **CR/LF**

3. **INSTRUCTION**

4. Key **0**  **CR/LF**
   or
   Key **1**  **CR/LF**

If you keyed 0, then go to Step 5. Otherwise go to Step 13.

5. **INSTRUCTION**

6. Key **# of OBS. Values**  **CR/LF**

7. **INSTRUCTION**

The observed and expected values are input as follows:

0₁, E₁  **CR/LF**
0₂, E₂  **CR/LF**

EXEMPLARY

<table>
<thead>
<tr>
<th>OBS</th>
<th>EXP</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>10</td>
</tr>
<tr>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>11</td>
<td>10</td>
</tr>
</tbody>
</table>

Find $X^2$, $P(X^2, 6-1)$

TO COMPUTE $X^2$  2 INPUT 0, TO COMPUTE $P(X^2, 2, V$) INPUT 1

4. Key **0**  **CR/LF**

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OPERATING INSTRUCTIONS (Cont)

8. Key $O_1 \div E_1 \quad \text{CR/LF}$
   \hspace{1cm} 8. Key $1 \div 1 \div 0 \quad \text{CR/LF}$
   Key $9 \div 1 \div 0 \quad \text{CR/LF}$
   Key $7 \div 1 \div 0 \quad \text{CR/LF}$
   Key $1 \div 3 \div 1 \div 0 \quad \text{CR/LF}$
   Key $6 \div 1 \div 0 \quad \text{CR/LF}$
   Key $1 \div 1 \div 0 \quad \text{CR/LF}$

9. Read

   \hspace{1cm} \text{CHI-SQUARE} = 5.2
   \hspace{1cm} \text{P(5.2, 5) = 0.6080355905271}

10. INSTRUCTION

11. Key $1 \quad \text{CR/LF}$ if you have
    \hspace{1cm} \text{MORE INPUT? (1 = YES, 0 = NO)}
    \hspace{1cm} \text{more input}
    Key $0 \quad \text{CR/LF}$ if you have no
    \hspace{1cm} \text{more input. Program halts.}

12. Go to Step 3.

13. INSTRUCTION

14. Key Deg. of Freedom
    \hspace{1cm} \text{DEGREES OF FREEDOM?}
    \hspace{1cm} \text{CR/LF}

15. INSTRUCTION

16. Key $X^2 \quad \text{CR/LF}$

17. Read

18. Go to Step 10.
# WANG 2200 SERIES PROGRAM

## CHI-SQUARE ANALYSIS

**TITLE**

---

**PS. 01-2200.01A-00FI-12-0** 6/1/73

**NUMBER**

2200A-01, 2215, 2216/2217

**DATE**

**EQUIPMENT**

---

## PROGRAM ABSTRACT

Computes for an N x M contingency table, the value of CHI-SQUARE.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td></td>
<td>1683</td>
</tr>
</tbody>
</table>

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Printed in U.S.A.
PROGRAM DESCRIPTION

Computes, for an N x M contingency table, the value of Chi-Square, the number of degrees of freedom, the expected value for each cell and the Chi-Square contribution from each cell.

N times M must be ≤ 50 and must be a multiple of 4.

FORMULAE

Expected Value for Each Cell

The expected value for cell (I, J) is the sum of the observed values of Row I times the sum of the observed values of column J divided by the total observed values.

\[ E_{1,1} = \sum_{J=1}^{m} O_{1,J} \times \sum_{I=1}^{N} O_{I,1} \div \sum_{I=1}^{N} \sum_{J=1}^{M} O_{I,J} \]

Chi-Square Contribution for Each Cell

\[ \chi^2 = \frac{(O - E)^2}{E} \]

Chi-Square = Σ of the individual contributions

Degrees of Freedom

\((# \ of \ Rows - 1) \times (# \ of \ Columns - 1)\)
### OPERATING INSTRUCTIONS

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>II</td>
<td>III</td>
</tr>
<tr>
<td>A</td>
<td>160</td>
<td>242</td>
</tr>
<tr>
<td>B</td>
<td>108</td>
<td>178</td>
</tr>
</tbody>
</table>

1. **Key** **RESET** **CLEAR** **CR/LF**
   **LOAD** **CR/LF**

2. **Key** **RUN** **CR/LF**

3. **INSTRUCTION**

4. **Key No. of Rows** **CR/LF**

5. **INSTRUCTION**

6. **Key No. of Cols.** **CR/LF**

7. **INSTRUCTIONS**

   The elements of the contingency table are entered row by row 4 elements/line. If the last elements to be inputed in a row do not make a set of 4, complete the set of 4 with the first elements in the next row. If it is the last row, complete it with zeroes. For example,

   ```
   1 2 3
   4 5 6
   7 8 9
   ```

   is inputed as follows:

   : 1, 2, 3, 4
   : 5, 6, 7, 8
   : 9, 0, 0, 0

8. **Key** **ELEMENT ROW BY ROW**
   **4 ELEMENTS/LINE** **CR/LF**

### EXAMPLE

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

8. **Key** 1 6 0 2 4 **2** 3 7 **2**
   1 0 8 **CR/LF**
   Key 1 7 8 1 8 0 0 **CR/LF**

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The expected value for each cell and its Chi-Square contribution is calculated and printed. Also the total Chi-Square is printed and the # of degrees of freedom.

9. Read Table

<table>
<thead>
<tr>
<th>OBSERVED VALUE</th>
<th>FOR EACH CELL</th>
<th>EXPECTED VALUE</th>
<th>CHI 2 CONTRIBUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>160</td>
<td></td>
<td>158.34724</td>
<td>1.7250775E-2</td>
</tr>
<tr>
<td>108</td>
<td></td>
<td>109.65276</td>
<td>2.4911481E-2</td>
</tr>
<tr>
<td>242</td>
<td></td>
<td>248.15612</td>
<td>.15271781</td>
</tr>
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<td>178</td>
<td></td>
<td>171.84388</td>
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<td>37</td>
<td></td>
<td>32.496635</td>
<td>.62407366</td>
</tr>
<tr>
<td>18</td>
<td></td>
<td>22.503365</td>
<td>.90121163</td>
</tr>
</tbody>
</table>

CHI-SQUARE = 1.9407019

DEGREES OF FREEDOM = 2
WANG 2200 SERIES PROGRAM

T-TEST

TITLE

PS. 01-2200.01A-00FI-13-0  6/1/73
NUMBER   DATE
2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT

Calculates the T-statistic to test whether or not two samples have the same population mean.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td></td>
<td>1428</td>
</tr>
</tbody>
</table>
PROGRAM DESCRIPTION

Calculates the t-statistic to test whether or not two samples have the same population means. The test is performed for one of the four following hypotheses.

Let $\mu_i$ = population mean for sample i.
$\sigma_i$ = standard deviation for sample i.

Hypothesis 1: $\mu_1 = K$; $K$ = a given value.
Hypothesis 2: $\mu_1 = \mu_2$; $\sigma_1 = \sigma_2$
Hypothesis 3: $\mu_1 = \mu_2$; $\sigma_1 \neq \sigma_2$
Hypothesis 4: $\mu_1 = \mu_2$; where samples 1 and 2 are paired variates.

Sample 1: $X_1, X_2, \ldots, X_n$; $N$ = no. of elements in sample 1.
Sample 2: $Y_1, Y_2, \ldots, Y_m$; $M$ = no. of elements in sample 2.

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right.
OPERATING INSTRUCTIONS

EXAMPLE

Hypotheses 4: \( \mu_1 = \mu_2 \)
12 pairs of elements

<table>
<thead>
<tr>
<th>Sample</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2.9</td>
<td>5.8</td>
</tr>
<tr>
<td>3.4</td>
<td>4.9</td>
</tr>
<tr>
<td>3</td>
<td>2.3</td>
</tr>
<tr>
<td>3.4</td>
<td>2.1</td>
</tr>
<tr>
<td>3.7</td>
<td>2.6</td>
</tr>
<tr>
<td>4</td>
<td>3.8</td>
</tr>
<tr>
<td>2.9</td>
<td>7.9</td>
</tr>
<tr>
<td>3.1</td>
<td>4</td>
</tr>
<tr>
<td>2.8</td>
<td>4.1</td>
</tr>
<tr>
<td>2.8</td>
<td>3.8</td>
</tr>
<tr>
<td>2.4</td>
<td>3.3</td>
</tr>
<tr>
<td>3</td>
<td>3.1</td>
</tr>
</tbody>
</table>

Find T and Degrees of freedom

1. Key **RESET** **CLEAR** **CR/LF**
   **LOAD** **CR/LF**

2. Key **RUN** **CR/LF**

3. **INSTRUCTION**

4. Key **HYPOTHESIS CODE**
   **CR/LF**

   **HYPOTHESIS TO BE TESTED?**

4. Key 4 **CR/LF**

   If Hypothesis is #4, go to Step 12.

5. **INSTRUCTION**

   **NO. OF ELEMENTS IN SAMPLE 1**

6. Key **NO. OF ELEMENTS IN SAMPLE 1**
   **CR/LF**

7. **INSTRUCTION**

   **ENTER SAMPLE 1**

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OPERATING INSTRUCTIONS (Cont)

Sample is inputted 4 elements/line completing the last input line with zeroes if necessary. For example, the sample 1, 2, 3, 4, 5, 6 would be inputted in 2 steps as follows:

1, 2, 3, 4
5, 6, 0, 0

Please note: each element of an input line is separated by a comma.

8. Key ELEMENTS OF SAMPLE 1 (4 ELEMENTS/LINE)

   [CR/LF]

   If hypothesis tested is 2 or 3, then go to Step 16.

9. INSTRUCTION

   ENTER GIVEN VALUE OF MEAN

10. Key VALUE OF MEAN [CR/LF]

11. Go to Step 16.

12. INSTRUCTION

   NO. OF PAIRS OF ELEMENTS?

13. Key NO. OF PAIRS OF ELEMENTS [CR/LF]

13. Key 1 .2 [CR/LF]

14. INSTRUCTION

   ENTER SAMPLES (1 PAIRS/LINE)

   The samples are inputted one pair of data/input line. That is,

   \[
   x_1, y_1 \\
   x_2, y_2 \\
   \vdots \\
   x_N, y_N
   \]

   Note: The pairs are separated by a comma.

   \( N = \text{No. of pairs of elements.} \)
OPERATING INSTRUCTIONS (Cont)

15. Key \( X_1 \) \( \cdot \) \( Y_1 \) CR/LF
    \( \cdot \)
    Key \( X_N \) \( \cdot \) \( Y_N \) CR/LF

16. Read

15. Key 2 \( \cdot \) 9 \( \cdot \) 5 \( \cdot \) 8 CR/LF
    \( \cdot \)
    Key 3 \( \cdot \) 3 \( \cdot \) 1 CR/LF

T VALUE = 1.677252659013

DEG. FREEDOM = 11

END PROGRAM
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WANG
2200
SERIES
PROGRAM

WILCOXON MATCHED-PAIRS SIGNED-RANK TESTS

TITLE

PS.01-2200.01A-00FI-14-0  6/1/73
NUMBER
DATE
2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT

Performs the Wilcoxon matched-pairs signed-ranks test on a set of N pairs of data.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td></td>
<td>1720</td>
</tr>
</tbody>
</table>

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PROGRAM DESCRIPTION

Performs the Wilcoxon matched-pairs signed-ranks test on a set of N pairs of data. Note: It is best to leave tie scores for a given pair out of the analysis. (N ≤ 130).


NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right.
OPERATING INSTRUCTIONS

EXAMPLE

For the following data, find T.

<table>
<thead>
<tr>
<th>12</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>10</td>
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<tr>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

1. Key **RESET**  **CLEAR**  **CR/LF**
   **LOAD**  **CR/LF**

2. Key **RUN**  **CR/LF**

3. **INSTRUCTION**

4. Key **NO. OF PAIRS**  **CR/LF**

5. **INSTRUCTION**

   **INPUT PAIRS OF DATA**

   The pairs \((X_1, Y_1)\) are inputted line by line as follows:

   \[
   : X_1, Y_1 \\
   : X_2, Y_2 \\
   \vdots \\
   : X_N, Y_N
   \]

   Note: The pairs are separated by a comma.

6. Key \(X_1 - Y_1\)  **CR/LF**
   Key \(X_2 - Y_2\)  **CR/LF**
   \vdots
   Key \(X_N - Y_N\)  **CR/LF**

6. Key 1 2 3 1 6  **CR/LF**
   Key 1 1 9  **CR/LF**
   \vdots
   Key 4 3  **CR/LF**

7. **Read**

   \( T = 6.5 \)

   **END PROGRAM**

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PROGRAM ABSTRACT

Performs the Mann-Whitney U test given two samples.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
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<td>1574</td>
</tr>
</tbody>
</table>

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PROGRAM DESCRIPTION

Performs the Mann-Whitney U-test given two samples. The size of samples 1 and 2 must be \( \leq 40 \).


NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word **INSTRUCTION** will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.
OPERATING INSTRUCTIONS

EXAMPLE

Find u for these 2 samples

Sample 1
4, 4, 1, 3, 2, 5, 5, 8, 9, 9
Sample 2
7, 6, 4, 7, 10, 8, 10, 8, 11, 9

1. Key **RESET**  **CLEAR**  **CR/LF**
   **LOAD**  **CR/LF**

2. Key **RUN**  **CR/LF**

3. **INSTRUCTION**

4. Key **SIZE OF SAMPLE 1**  **CR/LF**
   Key **1 0**  **CR/LF**

5. **INSTRUCTION**
   ENTER SAMPLE 1

Input samples 1 and 2 when requested. The samples are inputed 4 elements/line completing the last input line with zeroes if necessary. For example, the sample (1, 2, 3, 4, 5, 6, 8, 9, 10, 11) would be inputed in 3 steps as follows:

: 1, 2, 3, 4
: 5, 6, 7, 8
: 9, 10, 0, 0

Note: The elements of an input line are separated by a comma.

6. Key **SAMPLE 1(4 ELEMENTS/LINE)**
   **CR/LF**

7. The information for Sample 2 will be entered in the same manner as Sample 1. Therefore go to Step 3 and enter data of Sample 2.

8. Read

   **U = 21**

END PROGRAM

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<table>
<thead>
<tr>
<th>BLOCK</th>
<th>PROGRAM TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>NORMAL FREQUENCY AND DISTRIBUTION FUNCTIONS</td>
</tr>
<tr>
<td>17</td>
<td>NEGATIVE BINOMIAL DISTRIBUTION</td>
</tr>
<tr>
<td>18</td>
<td>BINOMIAL DISTRIBUTION</td>
</tr>
<tr>
<td>19</td>
<td>POISSON DISTRIBUTION</td>
</tr>
<tr>
<td>20</td>
<td>F-VALUE</td>
</tr>
<tr>
<td>21</td>
<td>T-VALUE</td>
</tr>
<tr>
<td>22</td>
<td>RANDOM NORMAL DEVIATES</td>
</tr>
</tbody>
</table>
WANG
2200
SERIES
PROGRAM

NORMAL FREQUENCY AND DISTRIBUTION FUNCTIONS
TITLE

PS.01-2200.01A-00FI-16-0 6/1/73
NUMBER DATE
2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT

Computes values of the normal frequency and normal distribution functions.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td></td>
<td>607</td>
</tr>
</tbody>
</table>

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PROGRAM DESCRIPTION

Computes values of the normal frequency and normal distribution functions. The frequency function is:

\[ f(x) = \frac{1}{\sqrt{2\pi}} \left( e^{-\frac{x^2}{2}} \right) \quad 0 \leq x \leq \infty \]

The distribution function is:

\[ Q(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{x} e^{-\frac{t^2}{2}} dt \]

Equations (1), (2) are for standardized variables. We say, Y is normal \((M, \sigma)\), if \(X = (Y-M)/\sigma\) has the distribution and frequency functions above (where \(M = \text{mean,} \sigma = \text{standard deviation}\). The program has the option to standardize the variable if it is not already standardized.

The distribution function is approximated as follows. Given an \(X \geq 0\), define \(Y = 1/(1+P*X)\), \(P = 0.33267\) then,

\[ Q(X) = 1 - e^{-\frac{X^2}{2}} \left( A_1 Y + A_2 Y^2 + A_3 Y^3 \right) \sqrt{2\pi} + E \]

where:

\[ |E| \leq 10^{-5} \]
\[ A_1 = 0.4361836 \]
\[ A_2 = -0.1201676 \]
\[ A_3 = 0.937298 \]

For \(X < 0\), \(Q(X) = 1 - Q(-X)\)
\[ f(X) = f(-X) \]

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. Whenever such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.
OPERATING INSTRUCTIONS

EXAMPLE

Find F(X), Q(X) for:
  a standardized variable = 1.5

1. Key RESET  CLEAR  CR/LF
    LOAD  CR/LF

2. Key RUN  CR/LF

3. INSTRUCTION

INPUT '0' FOR A STANDARDIZED VARIABLE OR '1' FOR A NON-STANDARDIZED VARIABLE

4. Key 0  CR/LF
   or
   Key 1  CR/LF

If you have a standardized variable go to Step 7. Otherwise, go to Step 5.

5. INSTRUCTION

6. Key MEAN : STD. DEV.  CR/LF

INPUT 'MEAN, STANDARD DEVIATION'

7. INSTRUCTION

INPUT 'X' (or '99999' TO END PROGRAM)

8. Key X  CR/LF
    1  -  5  CR/LF

F(X) = .1295175943551
Q(X) = .933198107297

9. Read:

10. INSTRUCTION

INPUT 'X'

11. Go to Step 8.
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NEGATIVE BINOMIAL DISTRIBUTION

TITLE

PS.01-2200.01A-00FI-17-0  6/1/73

NUMBER    DATE
2200A-01, 2215, 2216/2217

EQUIPMENT

PROGRAM ABSTRACT

Computes values of the Negative Binomial Distribution.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
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</thead>
<tbody>
<tr>
<td>17</td>
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<td>639</td>
</tr>
</tbody>
</table>
PROGRESS DESCRIPTION

The negative binomial distribution given by:

\[ P(K, R, P) = \frac{(R + K - 1)!}{K! (R-1)!} P^R Q^K \]

is a discrete distribution used in solving waiting time problems. It calculates the probability that the Rth success will occur at a given trial number R + K, in a succession of N Bernoulli trials. This program is restricted to R a positive integer.

The program computes \( P(K, R, P) \) and keeps a running sum of the probabilities calculated.

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. Whenever such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.

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OPERATING INSTRUCTIONS

1. Key **RESET** **CLEAR** **CR/LF**
   **LOAD** **CR/LF**

2. Key **RUN** **CR/LF**

3. **INSTRUCTION**

4. Key **K** **R** **P** **CR/LF**

5. Read:

6. **INSTRUCTION**

7. Go to Step 4.

EXAMPLE

Find \( P(K, R, P) \) for:

<table>
<thead>
<tr>
<th>K</th>
<th>R</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>.5</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>.5</td>
</tr>
</tbody>
</table>

and the sum of probabilities.

4. Key **1** **2** **5** **CR/LF**

   \( P(K, R, P) = .2499999999999 \)

   **INPUT 'K, R, P'**

4. Key **3** **4** **5** **CR/LF**

   \( P(K, R, P) = .15625 \)

   **INPUT 'K, R, P'**

4. Key **0** **0** **1** **CR/LF**

   **SUM OF PROBABILITIES = .4062499999999**

   **INPUT 'K, R, P'**

4. Key **0** **0** **0** **CR/LF**

END PROGRAM
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WANG
2200
SERIES
PROGRAM

BINOMIAL DISTRIBUTION

TITLE

PS.01-2200.01A-00F1-18-0  6/1/73
NUMBER              DATE
2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT

The program computes values of the Binomial Distribution.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
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</thead>
<tbody>
<tr>
<td>18</td>
<td></td>
<td>631</td>
</tr>
</tbody>
</table>

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PROGRAM DESCRIPTION

The binomial distribution given by:

\[ P(K, N, P) = \frac{N!}{K! \, (N-K)!} \, P^K \, Q^{N-K} \]

is a discrete distribution giving the probability of obtaining exactly K successes in N Bernoulli trials.

The program computes \( P(K, N, P) \) and keeps a running sum of the probabilities calculated.

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. Whenever such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.
OPERATING INSTRUCTIONS

EXAMPLE
Find $P(K, N, P)$ for

<table>
<thead>
<tr>
<th>K</th>
<th>N</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>.5</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>.5</td>
</tr>
</tbody>
</table>

and the sum of probabilities.

1. Key **RESET** **CLEAR** **CR/LF**
2. Key **LOAD** **CR/LF**
3. **INSTRUCTION**
4. Key $K \cdot N \cdot P$ **CR/LF**
5. Read:
   
P($K, N, P$) = .15625
6. **INSTRUCTION**
7. Go to Step 4.

INPUT 'K, N, P' (OR '0, 0, -1' TO PRINT THE SUM OF PROBABILITIES CALCULATED THUS FAR, OR '0, 0, 0' TO END PROGRAM)

4. Key $1 \cdot 5 \cdot .5$ **CR/LF**

INPUT 'K, N, P' 

Key $2 \cdot 5 \cdot .5$ **CR/LF**

P($K, N, P$) = .3124999999998

INPUT 'K, N, P' 

Key $0 \cdot 0 \cdot 1$ **CR/LF**

SUM OF PROBABILITIES = .4687499999998

INPUT 'K, N, P' 

Key $0 \cdot 0 \cdot 0$ **CR/LF**

END PROGRAM
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POISSON DISTRIBUTION

TITLE

PS.01-2200.01A-00FI-19-0  6/1/73
NUMBER  DATE
2200A-01, 2215, 2216/2217  EQUIPMENT

PROGRAM ABSTRACT

Computes values of the Poisson Distribution

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td></td>
<td>481</td>
</tr>
</tbody>
</table>
PROGRAM DESCRIPTION

The Poisson distribution given by:

\[ P(K, \lambda) = \frac{e^{-\lambda} \lambda^K}{K!} \]

is a discrete distribution concerned with the occurrence of relatively rare events. \( K \) is the frequency, \( P(K, \lambda) \) is the probability associated with that frequency, and \( \lambda \) is the expected frequency.

The program computes \( P(K, \lambda) \) and keeps a running total of the probabilities calculated.

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. Whenever such instructions occur the word **INSTRUCTION** will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.
### OPERATING INSTRUCTIONS

1. Key **RESET** **CLEAR** **CR/LF**
   **LOAD** **CR/LF**

2. Key **RUN** **CR/LF**

3. **INSTRUCTION**

4. Key **K** **LAMBDA** **CR/LF**

5. Read:

6. **INSTRUCTION**

7. Go to Step 4.

### EXAMPLE

Find \( P(K, \lambda) \) for

<table>
<thead>
<tr>
<th>( K )</th>
<th>( \lambda )</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>7</td>
<td>10</td>
</tr>
</tbody>
</table>

and the sum of probabilities

---

**INPUT 'K, LAMBDA' (OR '-1, -1' TO PRINT THE SUM OF THE PROBABILITIES CALCULATED THUS FAR, OR '0, 0' TO END PROGRAM).**

4. Key **9** **1** **0** **CR/LF**

\[ P(K, \text{LAMBDA}) = 0.125110035723 \]

**INPUT 'K, LAMBDA'**

Key **7** **1** **0** **CR/LF**

\[ P(K, \text{LAMBDA}) = 9.00792257E-02 \]

**INPUT 'K, LAMBDA'**

Key **1** **1** **1** **CR/LF**

**SUM OF PROBABILITIES = 0.2151892614230**

**INPUT 'K, LAMBDA'**

Key **0** **0** **CR/LF**

**END PROGRAM**

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# WANG 2200 SERIES PROGRAM

**F-VALUE**

**TITLE**

<table>
<thead>
<tr>
<th>NUMBER</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>PS. 01-2200.01A-00FI-20-0</td>
<td>6/1/73</td>
</tr>
</tbody>
</table>

**EQUIPMENT**

2200A-01, 2215, 2216/2217

## PROGRAM ABSTRACT

Computes values of the probability of the F-ratio.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td></td>
<td>725</td>
</tr>
</tbody>
</table>

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PROGRAM DESCRIPTION

Computes the probability of an $F$-ratio with $N$ degrees of freedom in the numerator and $D$ degrees of freedom in the denominator.

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. Whenever such instructions occur the word **INSTRUCTION** will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.
OPERATING INSTRUCTIONS

1. Key **RESET** **CLEAR** **CR/LF**
   **LOAD** **CR/LF**
2. Key **RUN** **CR/LF**
3. **INSTRUCTION**
4. Key **F-VALUE** **CR/LF**
5. **INSTRUCTION**
6. Key **DEG. FREEDOM IN NUMERATOR** **CR/LF**
7. **INSTRUCTION**
8. Key **DEG. FREEDOM IN DENOMINATOR** **CR/LF**
9. Read
10. **INSTRUCTION**

EXAMPLE

Find the value of the F-ratio of 28.7 with 1 degree of freedom in the numerator and 8 degrees of freedom in denominator.

F-VALUE? (TO END PROGRAM INPUT 99999)
4. Key 2 8 - 7 **CR/LF**
5. **INSTRUCTION**
6. Key 1 **CR/LF**
7. **INSTRUCTION**
8. Key 8 **CR/LF**
9. Read
10. **INSTRUCTION**

F-VALUE?

PROBABILITY OF F= 9.83000000E-04
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T-VALUE

TITLE

PS. 01-2200. 01A-00FI-21-0  6/1/73
NUMBER    DATE
2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT

Computes the probability of a T-value.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td></td>
<td>677</td>
</tr>
</tbody>
</table>
PROGRAM DESCRIPTION

Computes the probability of a T-value for a two-tailed test with N degrees of freedom.

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. Whenever such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.
OPERATING INSTRUCTIONS

1. Key **RESET** **CLEAR** **CR/LF**
   **LOAD** **CR/LF**
2. Key **RUN** **CR/LF**
3. **INSTRUCTION**
4. Key **T-VALUE** **CR/LF**
5. **INSTRUCTION**
6. Key **DEG. OF FREEDOM** **CR/LF**
7. Read:
8. **INSTRUCTION**

EXAMPLE

Find

\[ P(2.2) \text{ for 4 deg. of freedom} \]
\[ P(0.7) \text{ for 3 deg. of freedom.} \]

**T-VALUE?** (TO END PROGRAM INPUT 999999)

4. Key **2 - 2** **CR/LF**
5. **DEG. FREEDOM?**
6. Key **4** **CR/LF**
7. **PROBABILITY OF T = 9.22090000E-02**
8. **T-VALUE?**
9. Key **7** **CR/LF**
10. **DEG. FREEDOM?**
11. Key **3** **CR/LF**
12. **PROBABILITY OF T = .536536**
13. **T-VALUE?**
14. Key **9 9 9 9 9** **CR/LF**
15. **END PROGRAM**

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WANG
2200
SERIES
PROGRAM

RANDOM NORMAL DEVIATES

TITLE

PS.01-2200.01A-00FI-22-0  6/1/73
NUMBER    DATE
2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT

Generates random normal deviates.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td></td>
<td>335</td>
</tr>
</tbody>
</table>
PROGRAM DESCRIPTION

Generates random normal deviates with a mean of zero and a variance of one.


NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. Whenever such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.
OPERATING INSTRUCTIONS

1. Key **RESET**  **CLEAR**  **CR/LF**
   **LOAD**  **CR/LF**
2. Key **RUN**  **CR/LF**

3. INSTRUCTION

4. Key **No. of Random Normal Deviates**  **CR/LF**

5. Read

   **NO. OF RANDOM NORMAL DEVIATES**
   -1.383557232697  1.022692621501  1.215135834351  -1.364422279283
   -0.8948073958194  0.29488508845874  0.6570253793798  -0.5282952951161
   -1.255201373407  -0.9017867253492  -1.962471742495  -1.791781668457
   1.375546518128  0.3341626351156  -0.7562615685378  -0.7685680757243
   1.128744313775  -1.91963679351  -1.177084245428  -0.2473285189663

EXAMPLE

Find 20 Random Normal Deviates?

4. Key **2 0**  **CR/LF**

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MISCELLANEOUS STATISTICS

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>PROGRAM TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td>MEAN, VARIANCE, STANDARD DEVIATION I</td>
</tr>
<tr>
<td>24</td>
<td>MEAN, VARIANCE, STANDARD DEVIATION II</td>
</tr>
<tr>
<td>25</td>
<td>GEOMETRIC MEAN AND STANDARD DEVIATION</td>
</tr>
<tr>
<td>26</td>
<td>CROSS-COVARIANCE OF TIME SERIES</td>
</tr>
<tr>
<td>27</td>
<td>AUTO-COVARIANCE OF TIME SERIES</td>
</tr>
<tr>
<td>28</td>
<td>SYSTEM RELIABILITY</td>
</tr>
<tr>
<td>29</td>
<td>ERROR FUNCTION</td>
</tr>
</tbody>
</table>
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WANG
2200
SERIES
PROGRAM

MEAN, VARIANCE, STANDARD DEVIATION I
TITLE

PS.01-2200.01A-00FI-23-0  6/1/73
NUMBER  DATE
2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT

Computes the mean, variance and standard deviation for ungrouped data.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td></td>
<td>532</td>
</tr>
</tbody>
</table>
PROGRAM DESCRIPTION

Computes the mean, variance, and standard deviation for ungrouped data.

For a population:

\[
\text{mean} = \frac{\sum X_i}{N}
\]

\[
\text{variance} = \left( \frac{\sum X_i^2}{N} - \frac{(\sum X_i)^2}{N} \right) / N
\]

\[
\text{st. dev.} = \sqrt{\text{variance}}
\]

where:  \(N = \) no. of observations
\(X_1, X_2, \ldots, X_n = \) observed values

For a sample: the divisor in the variance formula is \(N - 1\) rather than \(N\).

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. Whenever such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.
OPERATING INSTRUCTIONS

EXAMPLE

Find the mean, variance and standard deviation of the following population.

Observed Values
2, 3, 4, 5, 6

1. Key **RESET** **CLEAR** **CR/LF**
   **LOAD** **CR/LF**

2. Key **RUN** **CR/LF**

3. **INSTRUCTION**
   INPUT 0 FOR A POPULATION, 1 FOR A SAMPLE

4. Key 0 **CR/LF**
   or
   Key 1 **CR/LF**

4. Key 0 **CR/LF**

5. **INSTRUCTION**
   NO. OF OBSERVATIONS

6. Key **NO. OF OBSERVATIONS** **CR/LF**
   6. Key 5 **CR/LF**

7. **INSTRUCTION**
   INPUT OBSERVATIONS 4/LINE

   The observed values are inputted 4/line. If necessary, complete the last input line with zeroes. Separate each element of an input line with a comma.

8. Key **OBSERVED VALUES (4/LINE)** **CR/LF**
   8. Key 2 , 3 , 4 , 5 **CR/LF**
   Key 6 , 0 , 0 , 0 **CR/LF**

9. Read
   MEAN = 4
   VARIANCE = 2
   ST. DEV. = 1.4142135624

END PROGRAM

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WANG
2200
SERIES
PROGRAM

MEAN, VARIANCE, STANDARD DEVIATION II

TITLE

PS.01-2200.01A-00FI-24-0 6/1/73
NUMBER DATE
2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT

Computes the mean, variance, and standard deviation for grouped data.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td></td>
<td>481</td>
</tr>
</tbody>
</table>

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PROGRAM DESCRIPTION

Computes the mean, variance, and standard deviation for grouped data.

For a population:

\[
\text{mean} = \left( \frac{\sum_{i=1}^{M} X_i f_i}{N} \right)
\]

\[
\text{variance} = \left( \frac{\sum_{i=1}^{M} X_i^2 f_i - \left( \frac{\sum_{i=1}^{M} X_i f_i}{N} \right)^2}{N} \right)
\]

\[
\text{st. dev.} = \sqrt{\text{variance}}
\]

where: \( X_i \) = ith observed value

\( f_i \) = number of times \( X_i \) occurred.

\[ N = \sum_{i=1}^{M} f_i \]

\( M \) = number of observed values.

For a sample, the divisor in the variance formula is \( N - 1 \) rather than \( N \).

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. Whenever such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.
EXAMPLE

Find mean, variance, and standard deviation for the following data taken from a population.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>freq</td>
</tr>
<tr>
<td>61</td>
<td>5</td>
</tr>
<tr>
<td>64</td>
<td>18</td>
</tr>
<tr>
<td>67</td>
<td>42</td>
</tr>
<tr>
<td>70</td>
<td>27</td>
</tr>
<tr>
<td>73</td>
<td>8</td>
</tr>
</tbody>
</table>

1. Key **RESET**  **CLEAR**  **CR/LF**
   **LOAD**  **CR/LF**

2. Key **RUN**  **CR/LF**

3. **INSTRUCTION**

4. Key 0  **CR/LF**
   or
   Key 1  **CR/LF**

5. **INSTRUCTION**

6. Key **NO. OF OBSERVATIONS**  **CR/LF**

7. **INSTRUCTION**

The observed value and its frequency is a data pair. Each data pair is an input line, where the two elements of the pair are separated by a comma.

8. Key \( X_1 \)  \( F_1 \)  **CR/LF**
   Key \( X_2 \)  \( F_2 \)  **CR/LF**
   \[\vdots\]
   Key \( X_M \)  \( F_M \)  **CR/LF**

8. Key 6  1  5  **CR/LF**
   Key 6  4  1  8  **CR/LF**
   \[\vdots\]
   Key 7  3  8  **CR/LF**

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9. Read

MEAN = 67.45
VARIANCE = 8.5275
ST. DEV. = 2.9201883501

END PROGRAM
WANG
2200
SERIES
PROGRAM

GEOMETRIC MEAN AND STANDARD DEVIATION

TITLE

PS. 01-2200. 01A-00FI-25-0  6/1/73
NUMBER    DATE
2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT

Computes the geometric mean and geometric standard deviation for a geometrically normal set of data.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td></td>
<td>368</td>
</tr>
</tbody>
</table>

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PROGRAM DESCRIPTION

Computes the geometric mean and geometric standard deviation for a geometrically normal set of data.

Geometric Mean = \((A_1 \cdot A_2 \cdot A_3 \cdots A_N)^{1/N}\)

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. Whenever such instructions occur the word **INSTRUCTION** will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.
OPERATING INSTRUCTIONS

EXAMPLE

Find the geometric mean and the geometric standard deviation for the following data:
10, 52, 63, 42, 12, 25, 95, 46, 48, 10

1. Key \textbf{RESET} \quad \textbf{CLEAR} \quad \textbf{CR/LF}
   \textbf{LOAD} \quad \textbf{CR/LF}

2. Key \textbf{RUN} \quad \textbf{CR/LF}

3. \textbf{INSTRUCTION}

4. Key \textbf{NO. OF DATA ELEMENTS} \quad \textbf{CR/LF}
   \textbf{CR/LF}

5. \textbf{INSTRUCTION}

6. Key $A_1$ \quad \textbf{CR/LF}
   Key $A_2$ \quad \textbf{CR/LF}
   $\vdots$
   Key $A_n$ \quad \textbf{CR/LF}

7. Read

NO. OF DATA ELEMENTS

4. Key 1 0 \quad \textbf{CR/LF}

DATA ELEMENTS 1/LINE

6. Key 1 0 \quad \textbf{CR/LF}
   Key 5 2 \quad \textbf{CR/LF}
   $\vdots$
   Key 1 0 \quad \textbf{CR/LF}

GEOMETRIC MEAN IS: 31.17049587113

GEOMETRIC STANDARD DEVIATION IS: 2.258031500973

END PROGRAM
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WANG
2200
SERIES
PROGRAM

CROSS-COVARIANCE OF TIME SERIES

TITLE

PS. 01-2200. 01A-00FI-26-0  6/1/73
NUMBER         DATE
2200A-01, 2215, 2216/2217  EQUIPMENT

PROGRAM ABSTRACT

Finds the cross-covariances of series A with series B (which leads and lags A).

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td></td>
<td>1793</td>
</tr>
</tbody>
</table>

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PROGRAM DESCRIPTION

Finds the cross-covariance of a series A with series B (which leads and lags A). The lag covariance and the lead covariance are calculated for lags and leads of 0, 1, 2, ..., L-1 where L ≤ N and N = number of elements in series A and B.

(N ≤ 70)

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. Whenever such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.
EXAMPLE

Find the cross-covariance of series A with series B (L = 5).

Series A
1, 2, 3, 4, 5, 6, 7, 8, 9, 10
Series B
3, 6, 11, 18, 27, 38, 51, 66, 83, 102

1. Key [RESET] [CLEAR] [CR/LF] [LOAD] [CR/LF]

2. Key [FUN] [CR/LF]

3. INSTRUCTION

4. Key N - L [CR/LF]

5. INSTRUCTION

4. Key 1 0 - 5 [CR/LF]

INPUT N, L

INPUT SERIES A AND B, 2 ELEMENTS/LINE i.e. A1, B1, CARRIAGE RETURN, A2, B2, CARRIAGE RETURN, . . . )

6. Key 1 - 3 [CR/LF]

7. Read

<table>
<thead>
<tr>
<th>LAG/LEAD</th>
<th>LAG COVARIANCE</th>
<th>LEAD COVARIANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>90.75</td>
<td>90.75</td>
</tr>
<tr>
<td>1</td>
<td>77.91666666667</td>
<td>63.25</td>
</tr>
<tr>
<td>2</td>
<td>59.25</td>
<td>34.25</td>
</tr>
<tr>
<td>3</td>
<td>34.25</td>
<td>4.25</td>
</tr>
<tr>
<td>4</td>
<td>2.41666666667</td>
<td>-26.25</td>
</tr>
</tbody>
</table>
# WANG 2200 SERIES PROGRAM

AUTO COVARIANCE OF A TIME SERIES

**Title**

PS. 01-2200.01A-00FI-27-0  6/1/73

**Number**

2200A-01, 2215, 2216/2217

**Equipment**

## PROGRAM ABSTRACT

Finds the auto-covariance of a time series.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td></td>
<td>1345</td>
</tr>
</tbody>
</table>

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PROGRAM DESCRIPTION

Finds the autocovariances of a time series for lags of 0 to \( L \) where \( L \leq N \) and \( N = \) number of elements in the series. \((N \leq 96)\)

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. Whenever such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.
OPERATING INSTRUCTIONS

EXAMPLE

For the time series

\[ 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 \]
\[ 13, 14, 15, 16 \]

find autocovariances for 7 lags

1. Key \[ \text{RESET} \] \[ \text{CLEAR} \] \[ \text{CR/LF} \]
   \[ \text{LOAD} \] \[ \text{CR/LF} \]

2. Key \[ \text{RUN} \] \[ \text{CR/LF} \]

3. \text{INSTRUCTION}

4. Key \[ N \] \[ L \] \[ \text{CR/LF} \]

5. \text{INSTRUCTION}

INPUT \( N, L \)

4. Key \[ 1 \] \[ 6 \] \[ 7 \] \[ \text{CR/LF} \]

INPUT SERIES, 4 ELEMENTS/LINE. IF NECESSARY FILL LAST INPUT LINE WITH ZEROES.

The series \( A_1, A_2, \ldots, A_N \) is inputed 4 elements/line. Complete the last line with zeroes if necessary. For example, 1, 2, 3, 4, 5, 6 is inputed as follows:

\[ 1, 2, 3, 4, \text{CR/LF} \]
\[ 5, 6, 0, 0, \text{CR/LF} \]

6. Key \[ A_1 \] \[ A_2 \] \[ A_3 \] \[ A_4 \] \[ \text{CR/LF} \]

Continue until all elements have been entered.

6. Key \[ 1 \] \[ 2 \] \[ 3 \] \[ 4 \] \[ \text{CR/LF} \]
   Key \[ 5 \] \[ 6 \] \[ 7 \] \[ 8 \] \[ \text{CR/LF} \]
   Key \[ 9, , 1, 0, , 1, , 1, , , 1, , 2, \]
   \[ \text{CR/LF} \]
   Key \[ 1 \] \[ 3 \] \[ 1 \] \[ 4 \] \[ , 1 \] \[ 5 \] \[ , 1 \] \[ 6 \]
   \[ \text{CR/LF} \]

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7. Read:

<table>
<thead>
<tr>
<th>LAGS</th>
<th>AUTOCOVARIANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>21.25</td>
</tr>
<tr>
<td>1</td>
<td>18.41666666667</td>
</tr>
<tr>
<td>2</td>
<td>15.25</td>
</tr>
<tr>
<td>3</td>
<td>11.75</td>
</tr>
<tr>
<td>4</td>
<td>7.91666666667</td>
</tr>
<tr>
<td>5</td>
<td>3.75</td>
</tr>
<tr>
<td>6</td>
<td>-0.75</td>
</tr>
</tbody>
</table>
WANG
2200
SERIES
PROGRAM

SYSTEM RELIABILITY

TITLE

PS.01-2200.01A-00F1-28-0  6/1/73
NUMBER  DATE
2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT

Calculates the system reliability when chance failure is present along with wearout.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td></td>
<td>327</td>
</tr>
</tbody>
</table>
PROGRAM DESCRIPTION

Calculates the system reliability when chance failure is present along with wearout.

\[ R = e^{-X}, \quad X = \sum_{i=1}^{N} \left( L_i + \frac{1}{M_i} \right) t \]

where:

- \( R \) = system reliability
- \( M_i \) = mean wearout time of \( i \)th component (hrs.)
- \( L_i \) = chance failure rate of \( i \)th component
- \( t \) = operating time (hrs.)

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. Whenever such instructions occur the word **INSTRUCTION** will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.
OPERATING INSTRUCTIONS

EXAMPLE

<table>
<thead>
<tr>
<th>Component</th>
<th>Mean Wearout</th>
<th>Chance Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6000</td>
<td>.0001</td>
</tr>
<tr>
<td>2</td>
<td>6500</td>
<td>.00015</td>
</tr>
<tr>
<td>3</td>
<td>7000</td>
<td>.0002</td>
</tr>
</tbody>
</table>

Operating Time = 1000
Find value of system reliability

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]

2. Key [RUN] [CR/LF]

3. **INSTRUCTIONS**

4. Key NO. OF COMPONENTS [CR/LF]
   OPERATING TIME [CR/LF]

5. **INSTRUCTION**

6. Key MEAN WEAROUT TIME [CR/LF]
   CHANCE FAILURE, [CR/LF]

The program will loop to Step 5 until the mean wearout time and chance failure rate for each component has been inputted. After all components have been entered go to Step 7.

7. Read: SYSTEM RELIABILITY = .4011700152417

END PROGRAM

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WANG
2200
SERIES
PROGRAM

ERROR FUNCTION

TITLE

PS. 01-2200. 01A-00FI-29-0       6/1/73
NUMBER       DATE
2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT

Computes values of the error function.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>29</td>
<td></td>
<td>1034</td>
</tr>
</tbody>
</table>

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PROGRAM DESCRIPTION

Computes the definite integral of the function

\[ E(X) = \frac{2}{\sqrt{\pi}} e^{-X^2} \]

between the limits of 0 and X, using the trapezoidal rule with Romberg's extrapolation. The integral is calculated to 4 significant digits.

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. Whenever such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.
OPERATING INSTRUCTIONS

1. Key **RESET** **CLEAR** **CR/LF**
   **LOAD** **CR/LF**

2. Key **RUN** **CR/LF**

3. **INSTRUCTION**

4. Key X **CR/LF**

5. Read

6. **INSTRUCTION**

EXAMPLE

Find the value of the error function at 3 and 5.

TO END PROGRAM INPUT 0.
INPUT 'INTEGRATION LIMIT X'

4. Key 3 **CR/LF**

INTEGRAL = .9999779835828

INPUT 'INTEGRATION LIMIT X'

Key 5 **CR/LF**

INTEGRAL = .9999989816139

INPUT 'INTEGRATION LIMIT X'

Key 0 **CR/LF**

END PROGRAM
This page intentionally left blank
<table>
<thead>
<tr>
<th>BLOCK</th>
<th>PROGRAM TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>TALBOT'S FORMULA</td>
</tr>
<tr>
<td>31</td>
<td>MANNING'S FORMULA</td>
</tr>
<tr>
<td>32</td>
<td>HEADLOSS IN A PIPE</td>
</tr>
<tr>
<td>33</td>
<td>BERNOULLI'S EQUATION</td>
</tr>
<tr>
<td>34</td>
<td>WARPING STRESS DUE TO TEMPERATURE DIFFERENTIAL</td>
</tr>
<tr>
<td>35</td>
<td>PRESSURE DUE TO SURFACE LOADS, PRINT LOADS, FINITE OR INFINITE LINE LOADS</td>
</tr>
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<td>36</td>
<td>BEAM</td>
</tr>
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<td>40</td>
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</tr>
</tbody>
</table>
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WANG
2200
SERIES
PROGRAM

TALBOT'S FORMULA

TITLE

PE.11-2200.01A-00FI-1-0  6/1/73
NUMBER  DATE
2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT

Estimates the area of waterway opening required for culverts.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td></td>
<td>217</td>
</tr>
</tbody>
</table>

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PROGRAM DESCRIPTION

Talbot's formula is one of the best known empirical formulas for estimating the area of waterway opening required for culverts.

\[ a = CA^{3/4} \]

where:

- \( a \) = Required Waterway Opening
- \( A \) = Drainage Area (Acres)
- \( C \) = Runoff Coefficient

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.
OPERATING INSTRUCTIONS

1. Key **RESET**  **CLEAR**  **CR/LF**
   **LOAD**  **CR/LF**

2. Key **RUN**  **CR/LF**

3. **INSTRUCTION**

4. Key Area (in Acres)  **CR/LF**

5. **INSTRUCTION**

6. Key Runoff Coeff.  **CR/LF**

7. Read

DRAINAGE AREA?

4. Key 2  **CR/LF**

RUNOFF COEFF.?

6. Key 5  **CR/LF**

REQUIRED WATERWAY OPENING = .8722369398

MORE INPUT? (1 = YES, 0 = NO)

8. **INSTRUCTION**

9. Key 0  **CR/LF**
   or
   Key 1  **CR/LF**

END PROGRAM

If you have more input, go to Step 3. Otherwise, go to Step 10.

A = 2.1 acres

C = .5
This page intentionally left blank
MANNING'S FORMULA

PROGRAM ABSTRACT

Computes the discharge quantity for open channel flow.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td></td>
<td>411</td>
</tr>
</tbody>
</table>
PROGRAM DESCRIPTION

This program combines Manning's formula for velocity of water flow with the general flow formula to determine the discharge quantity for open-channel flow.

\[ Q = \frac{1.486}{n} AR^{2/3} S^{1/2} \]

where:

- \( Q \) = Discharge (ft\(^3\)/sec)
- \( A \) = Area of flow cross section (ft\(^2\))
- \( n \) = Manning's roughness coefficient
- \( R \) = Hydraulic radius (ft)
- \( S \) = Slope of channel (ft/ft)

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.
OPERATING INSTRUCTIONS

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]
2. Key [RUN] [CR/LF]
3. INSTRUCTION
4. Key A [CR/LF]
5. INSTRUCTION
6. Key n [CR/LF]
7. INSTRUCTION
8. Key R [CR/LF]
9. INSTRUCTION
10. Key S [CR/LF]
11. Read
12. INSTRUCTION
13. Key 0 [CR/LF]
    or
    Key 1 [CR/LF]

If you have more input, go to Step 3. Otherwise, go to Step 14.

END PROGRAM

EXAMPLE
A = 20 ft^2
S = .003
n = .03
R = 2.5 ft.

AREA OF FLOW CROSS SECTION (SQ. FT.)?
4. Key 2 0 [CR/LF]
MANNING'S ROUGHNESS COEFF.?
6. Key - 0 3 [CR/LF]
HYDRAULIC RADIUS (FT.)?
8. Key 2 - 5 [CR/LF]
SLOPE OF CHANNEL (FT./FT.)?
10. Key - 0 0 3 [CR/LF]

DISCHARGE = 99.94970504597 CU. FT.?SEC.

MORE INPUT? (1 = YES, 0 = NO)
13. Key 0 [CR/LF]
WANG
2200
SERIES
PROGRAM

HEADLOSS IN A PIPE

TITLE

PE.11-2200.01A-00FI-3-0          6/1/73
NUMBER          DATE
2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT

Computes the headloss between two reservoirs on different levels.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
<td></td>
<td>337</td>
</tr>
</tbody>
</table>

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PROGRAM DESCRIPTION

This program calculates the head loss between two reservoirs on different levels. Friction factor, pipe O.D. and length of the line are related to the head loss which is calculated in the following formula:

\[
H = \left[ f \frac{L}{D} + 1.5 \right] \frac{V^2}{2a}
\]

\[
H = \left[ f \frac{L}{D} + 1.5 \right] \left[ \frac{16/\left(\pi \cdot D^2\right)}{64.4} \right]^2
\]

where:
- \(H\) = Head loss in ft.
- \(L\) = Length in ft.
- \(D\) = O-Diameter of pipe in ft.
- \(f\) = Friction Factor

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.
OPERATING INSTRUCTIONS

1. Key **RESET**  **CLEAR**  **CR/LF**
   **LOAD**  **CR/LF**

2. Key **RUN**  **CR/LF**

3. **INSTRUCTION**

4. Key **L**  **CR/LF**

5. **INSTRUCTION**

6. Key **D**  **CR/LF**

7. **INSTRUCTION**

8. Key **f**  **CR/LF**

9. Read

10. **INSTRUCTION**

11. Key **0**  **CR/LF**
    or
    Key **1**  **CR/LF**

   If you have more input, go to Step 3. Otherwise go to Step 12.

12. **END PROGRAM**

EXAMPLE

\[ L = 150' \]
\[ f = 0.013 \]
\[ D = 0.667' \]

LENGTH (FT)?

4. Key **1 5 0**  **CR/LF**

0-DIAMETER OF PIPE (FT.)?

6. Key **6 6 7**  **CR/LF**

FRICITION FACTOR

8. Key **0 1 3**  **CR/LF**

HEADLOSS = 9.01622697414

MORE INPUT? (1=YES, 0=NO)

11. Key **0**  **CR/LF**
This page intentionally left blank
**BERNOULLI'S EQUATION**

**PROGRAM ABSTRACT**

Computes the headwater depth of culverts flowing full.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>33</td>
<td></td>
<td>424</td>
</tr>
</tbody>
</table>
PROGRAM DESCRIPTION

This program uses Bernoulli's equation to compute the headwater depth of Culverts flowing full.

\[ H = (1 + K_e + \frac{2}{R^{4/3}} \cdot \frac{9n^2 L}{4/3} \cdot \frac{V^2}{2g}) \]

where:

\( H = \) DIFFERENCE IN ELEVATION BETWEEN HEADWATER ELEVATION AND ELEVATION OF TAILWATER SURFACE, OR DIFFERENCE BETWEEN HEADWATER ELEVATION AND CROWN AT OUTLET WHEN CULVERT IS FLOWING FULL WITHOUT TAILWATER BEING ABOVE CROWN (FT)

\( \frac{V^2}{2g} = \) Velocity Head (ft)

\( K_e = \) Coefficient of Entrance Loss.

\( n = \) Manning's Roughness Coefficient

\( L = \) Length of Culvert (ft)

\( R = \) Hydraulic Radius (ft)

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.
### OPERATING INSTRUCTIONS

#### EXAMPLE

- \( R = 2.5 \text{ ft.} \)
- \( L = 70 \text{ ft.} \)
- \( n = 0.015 \)
- \( K_e = 0.2 \)
- \( V^2/2g = 0.8 \text{ ft.} \)

1. Key **RESET**  **CLEAR**  **CR/LF**
   **LOAD**  **CR/LF**
2. Key **RUN**  **CR/LF**
3. **INSTRUCTION**
4. Key \( V^2/2g \)  **CR/LF**
5. **INSTRUCTION**
6. Key \( K_e \)  **CR/LF**
7. **INSTRUCTION**
8. Key \( n \)  **CR/LF**
9. **INSTRUCTION**
10. Key \( L \)  **CR/LF**
11. **INSTRUCTION**
12. Key \( R \)  **CR/LF**
13. Read
14. **INSTRUCTION**
15. Key \( 0 \)  **CR/LF**
   or
   Key \( 1 \)  **CR/LF**

**VELOCITY HEAD (FT.)?**

4. Key \( + \)  **8**  **CR/LF**

**COEFF. OF ENTRANCE LOSS?**

6. Key \( + \)  **2**  **CR/LF**

**MANNING'S ROUGHNESS COEFF.?**

8. Key \( + \)  **0**  **1**  **5**  **CR/LF**

**LENGTH OF CULVERT (FT.)?**

10. Key \( + \)  **7**  **0**  **CR/LF**

**HYDRAULIC RADIUS (FT.)?**

12. Key \( + \)  **2**  **5**  **CR/LF**

**HEADWATER DEPTH (FT.) = 1.0676916087**

**MORE INPUT? (1 = YES, 0 = NO)**

15. Key \( 0 \)  **CR/LF**

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If you have more input, go to Step 3. Otherwise, go to Step 16.

16. END PROGRAM
WANG
2200
SERIES
PROGRAM

WARPING STRESS DUE TO A TEMPERATURE DIFFERENTIAL
TITLE

PE.11-2200.01A-00F1-5-0  6/1/73
NUMBER  DATE
2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT

Computes the warping stress in two directions which exist in the center of a slab of concrete pavement.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>34</td>
<td></td>
<td>470</td>
</tr>
</tbody>
</table>

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PROGRAM DESCRIPTION

This program computes the warping stress in two directions which exist in the center of a slab of concrete pavement.

\[ S_t = \frac{E_c \, t}{2} \left( \frac{C_1 + \mu C_2}{1 - \mu^2} \right) \]

where:

- \( S_t \) = warping stress (psi)
- \( E_c \) = modulus of elasticity of concrete (psi)
- \( t \) = temperature differential
- \( C_1 \) = coefficient of slab length in desired direction
- \( C_2 \) = coefficient of slab length normal to \( C_1 \)

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.
OPERATING INSTRUCTIONS

EXAMPLE

\[ C_2 = -1.265 \]
\[ C_1 = 1.265 \]
\[ E_c = 5,000,000 \text{ psi} \]
\[ t = 20 \]

1. Key **RESET** [ CLEAR ] [ CR/LF ]
   [ LOAD ] [ CR/LF ]
2. Key **RUN** [ CR/LF ]
3. **INSTRUCTION**
4. Key \( \frac{E_c}{C_1} \) [ CR/LF ]
5. **INSTRUCTION**
6. Key \( t \) [ CR/LF ]
7. **INSTRUCTION**
8. Key \( C_1 \) [ CR/LF ]
9. **INSTRUCTION**
10. Key \( C_2 \) [ CR/LF ]
11. Read
12. **INSTRUCTION**
13. Key \( 0 \) [ CR/LF ]
    or
    Key \( 1 \) [ CR/LF ]

MODULUS OF ELASTICITY OF CONCRETE (PSI)?

4. Key \( 5 \ 0 \ 0 \ 0 \ 0 \ 0 \) [ CR/LF ]

TEMPERATURE DIFFERENTIAL?

6. Key \( 2 \ 0 \) [ CR/LF ]

COEFF. OF SLAB LENGTH IN DESIRED DIRECTION?

8. Key \( 1 \ 2 \ 6 \ 5 \) [ CR/LF ]

COEFF. OF SLAB LENGTH NORMAL TO C1?

10. Key \( -1 \ 2 \ 6 \ 5 \) [ CR/LF ]

WARPING STRESS = 275

MORE INPUT? (1 = YES, 0 = NO)

13. Key \( 0 \) [ CR/LF ]

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If you have more input, go to Step 3. Otherwise, go to Step 14.

14. END PROGRAM
WANG
2200
SERIES
PROGRAM

PRESSURE DUE TO SURFACE LOADS - POINT LOAD, FINITE & INFINITE LINE LOADS

TITLE

PE. 11-2200.01A-00FI-6-0  6/1/73
NUMBER    DATE
2200A-01, 2215, 2216/2217
EQUIPMENT

PROGRAM ABSTRACT

This program computes horizontal unit pressure due to a point load, or lateral pressure due to a line load either finite or infinite.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>35</td>
<td></td>
<td>475</td>
</tr>
</tbody>
</table>

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PROGRAM DESCRIPTION

CASE 1  This program computes horizontal unit pressure due to a point load, such as a truck wheel, at any point on the wall of a backfill surface.

\[ h_c = p \frac{X^2 Z}{R^5} \]

where:

\[ R = \sqrt{X^2 + Y^2 + Z^2} \]

\( h_c \) = Horizontal unit pressure (psf)
\( P \) = Applied point load (lbs)
\( X \) = Horizontal distance from load to wall (ft)
\( Y \) = Lateral distance from load to point on wall (ft)
\( Z \) = Vertical distance from load to point on wall (ft)

CASE 2  This program computes lateral pressure due to a line load or a narrow strip load of finite length at any depth opposite one end of a parallel strip load on the backfill.

\[ h_s = \frac{P}{\pi} \frac{X^2 Z}{R_1^4} \left[ \frac{R_1^2 Y_1}{3 (R_1^2 + Y_1^2)^{3/2}} + \frac{2Y_1}{3(R_1^2 + Y_1^2)^{1/2}} \right] \]

where:

\[ R_1 = \sqrt{X^2 + Z^2} \]

\( h_s \) = Unit lateral pressure (psf)
\( P \) = Load per unit length of strip (lbs/ft)
\( X \) = Distance back of wall (ft)
\( Z \) = Depth of pressure (ft)
\( Y_1 \) = Length of strip load (ft)
CASE 3  This program computes the lateral unit pressure due to a line load or narrow strip of infinite length at any depth opposite one end of a parallel strip load on the backfill.

\[ h_s = \frac{4}{3} \frac{P_s}{R_1} \frac{X^2 Z}{R_1^4} \]

where:

\[ R_1 = \sqrt{X^2 + Z^2} \]

\( h_s \) = Unit lateral pressure (psf)

\( P_s \) = Load per unit length of strip (lb/ft)

\( X \) = Distance back of wall (ft)

\( Z \) = Depth of pressure (ft)

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word \textbf{INSTRUCTION} will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.
CASE 1

OPERATING INSTRUCTIONS

EXAMPLE

\[
\begin{align*}
X &= 10.5 \text{ ft.} = \text{horizontal distance from load to wall (ft)} \\
Y &= 11.25 \text{ ft.} = \text{lateral distance from load to point on wall (ft)} \\
Z &= 12.0 \text{ ft.} = \text{vertical distance from load to point on wall (ft)} \\
P &= 6,000 \text{ lbs.} = \text{applied point load}
\end{align*}
\]

1. Key \text{RESET} \text{ CLEAR} \text{ CR/LF} \text{ LOAD} \text{ CR/LF}

2. Key \text{RUN} \text{ CR/LF}

3. \text{INSTRUCTION}

4. Key \text{CASE NO.} \text{ CR/LF}

5. \text{INSTRUCTION}

6. Key \text{APPLIED POINT LOAD} \text{ HORIZONTAL DISTANCE} \text{ LATERAL DISTANCE} \text{ VERTICAL DISTANCE} \text{ CR/LF}

7. Read:

\[
HC = 2.805001552062
\]

8. \text{INSTRUCTION}

9. Key 0 \text{ CR/LF}

\text{or}

Key 1 \text{ CR/LF}

\text{If you have another case go to Step 3. Otherwise, go to Step 10.}

10. \text{END PROGRAM}
CASE 2

OPERATING INSTRUCTIONS

EXAMPLE

\[ X = 10.5 \text{ ft. Distance Back of Wall (ft)}. \]
\[ Z = 12 \text{ ft. Depth of pressure (ft)} \]
\[ Y_1 = 11.25 \text{ ft. Length of Strip Load (ft)} \]
\[ P_s = 6,000 \text{ lb/ft. Load per unit length of strip}. \]

1. Key \textbf{RESET} \textbf{CLEAR} \textbf{CR/LF} \textbf{LOAD} \textbf{CR/LF}

2. Key \textbf{RUN} \textbf{CR/LF}

3. \textbf{INSTRUCTION}

4. Key \textbf{CASE NO.} \textbf{CR/LF}

5. \textbf{INSTRUCTION}

6. Key \textbf{LOAD/UNIT LENGTH OF STRIP} \textbf{DISTANCE BACK OF WALL} \textbf{LENGTH OF STRIP LOAD} \textbf{DEPTH OF PRESSURE} \textbf{CR/LF}

7. Read

8. \textbf{INSTRUCTION}

9. Key 0 \textbf{CR/LF} or Key 1 \textbf{CR/LF}

If you have another case, go to Step 3. Otherwise, go to Step 10.

10. END PROGRAM

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CASE 3

OPERATING INSTRUCTIONS

EXAMPLE

\[ X = 10.5 \text{ ft.} \quad \text{Distance back of wall} \]
\[ Z = 12 \text{ ft.} \quad \text{Depth pressure} \]
\[ P_s = 6,000 \text{ lb/ft.} \quad \text{Load per unit length of strip.} \]

1. Key [RESET] [CLEAR] [CR/LF]
   [LOAD] [CR/LF]

2. Key [RUN] [CR/LF]

3. INSTRUCTION
4. Key CASE NO. [CR/LF]
5. INSTRUCTION
6. Key LOAD PER UNIT LENGTH OF STRIP
   · DISTANCE BACK OF WALL,
   · DEPTH PRESSURE, [CR/LF]
7. Read
8. INSTRUCTION
9. Key 0 [CR/LF]
   or
   Key 1 [CR/LF]

If you have another case, go to Step 3. Otherwise, go to Step 10.

10. END PROGRAM

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WANG 2200 SERIES PROGRAM

BEAM

TITLE

PE.11-2200.01A-00F1-7-0 6/1/73
NUMBER DATE
2200A-01, 2215, 2216/2217

EQUIPMENT

PROGRAM ABSTRACT

Program recommends steel beams to use for a number of common applications.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td></td>
<td>2713</td>
</tr>
</tbody>
</table>

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PROGRAM DESCRIPTION

This program recommends steel beams to use for a number of common applications.

Input L, B, S, W, P, A when requested.

1  for uniformly distributed load
2  for single midpoint load
L = 3  for uniform load plus single midpoint load
4  for two equal symmetric loads

1  for beam supported at both ends
2  for one end fixed, other end supported
B = 3  for beam fixed at both ends
4  for one end fixed (cantilever)

S = length of span in feet

W = distributed load in pounds per foot
(set = 0 if not applicable)

P = each concentrated load in pounds
(set = 0 if not applicable)

A = location of load(s) in feet from end
(set = 0 if not applicable)

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. Whenever such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.
OPERATING INSTRUCTIONS

1. Key **RESET** **CLEAR** **CR/LF**
   **LOAD** **CR/LF**

2. Key **RUN** **CR/LF**

3. **INSTRUCTION**

4. Key L B S W P A **CR/LF**

5. Read

6. **INSTRUCTION**

7. Key 0 **CR/LF**
   or
   Key 1 **CR/LF**

If you have more input, program goes to Step 3. Otherwise, program ends.

EXAMPLE

Determine the recommended beam for the following data:

\[
\begin{align*}
L &= 1 \\
B &= 1 \\
S &= 20 \text{ ft.} \\
W &= 50 \text{ lbs/ft.} \\
P &= 0 \\
A &= 0
\end{align*}
\]

L, B, S, W, P, A?

Key \[1 1 2 0 5 0 0 0 \] **CR/LF**

RECOMMENDED BEAM IS A 6 JR 4.4

MORE INPUT (1 = YES, 0 = NO)

7. Key 0 **CR/LF**
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## OIL WELL DEPLETION

**TITLE**

**PE. 04-2200. 01A-00FI-4-0**  
**NUMBER**  
**2200A-01, 2215, 2216/2217**  
**DATE**  
**6/1/73**  
**EQUIPMENT**

### PROGRAM ABSTRACT

Calculates the number of years that an oil well will produce.

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
<th>BYTES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>37</td>
<td></td>
<td>624</td>
</tr>
</tbody>
</table>
PROGRAM DESCRIPTION

This program calculates the number of years that an oil well will produce given the current production rate, the minimum number of barrels of oil that must be produced to cover expenses and the reserve to be recovered on decline.

\[
D = \frac{C}{I \log \left( \frac{I}{q} \right)}
\]

\[
Y = \frac{D}{12} \left[ \frac{I}{q} - 1 \right]
\]

where:

- \( C \) = Reserve to be recovered on decline (barrels)
- \( I \) = Initial rate (barrels/month)
- \( q \) = Economic limit rate (barrels/month)
- \( D \) = Decline rate (months)
- \( Y \) = Life of decline production of oil well (years)

It also computes the cumulative production for each year plus the unit production for each year.

\[
CP_n = \log \left( \frac{12N}{D} + 1 \right) DI
\]

\[
P_n = CP_n - CP_{n-1}
\]

where:

- \( CP_n \) = cumulative production for nth year
- \( P_n \) = unit production for nth year

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.
OPERATING INSTRUCTIONS

EXAMPLE

Given:
Reserve to be recovered on decline = 50,000 barrels
Initial rate = 1000 barrels/months
Economic Limit Rate = 200 barrels/months
Find the decline rate (months) and the life of decline production of oil well (years)?

1. Key RESET  CLEAR  CR/LF
   LOAD  CR/LF
2. Key RUN  CR/LF
3. INSTRUCTION
4. Key RESERVE CR/LF
5. INSTRUCTION
6. Key INITIAL RATE CR/LF
7. INSTRUCTION
8. Key ECONOMIC LIMIT RATE, CR/LF
9. Read

RESERVE TO BE RECOVERED ON DECLINE (BARRELS)

4. Key 5 0 0 0 0 CR/LF
INITIAL RATE (BARRELS/MO.)?

6. Key 1 0 0 0 CR/LF
ECONOMIC LIMIT RATE (BARRELS/MO.)?

8. Key 2 0 0 CR/LF

Y = 10.35558224267

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10. Read

CP( 1 ) = 10146.80805834
P( 1 ) = 10146.80805834
CP( 2 ) = 17782.85486478
P( 2 ) = 7636.04680644
CP( 3 ) = 23907.42529636
P( 3 ) = 6124.57043158
CP( 4 ) = 29021.13755731
P( 4 ) = 5113.71226095
CP( 5 ) = 33410.87903326
P( 5 ) = 4389.74147595
CP( 6 ) = 37256.44790239
P( 6 ) = 3845.56886913
CP( 7 ) = 40678.00149686
P( 7 ) = 3421.55359447
CP( 8 ) = 43759.8273348
P( 8 ) = 3081.82583794
CP( 9 ) = 46563.33706577
P( 9 ) = 2803.50973097
CP( 10 ) = 49134.66211213
P( 10 ) = 2571.32504636
CP( 11 ) = 50000
P( 11 ) = 865.33788787

11. INSTRUCTION

MORE INPUT? (1 = YES, 0 = NO)

12. Key 0 or 1 [CR/LF]

If you key 1 [CR/LF], program will go to Step 3. Otherwise program ends.
WANG
2200
SERIES
PROGRAM

NETWORK IMPEDANCE - FINDING A SERIES OR PARALLEL CIRCUIT
TITLE

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<td>EQUIPMENT</td>
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PROGRAM ABSTRACT

This program is designed to find a series (parallel) circuit that is in parallel (series) by the leaning-ladder method.

<table>
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<td>393</td>
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</table>

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PROGRAM DESCRIPTION

CASE 1  This program is designed to find a series circuit that is in parallel by the leaning-ladder method

\[ R_s = \frac{R_p X_p^2}{(X_p^2 + R_p^2)} \]

\[ X_s = \frac{X_p R_p^2}{(X_p^2 + R_p^2)} \]

where:

\( R_s \) = Resistance to be in series (ohms)

\( X_s \) = Reactance to be in series (ohms)

\( R_p \) = Resistance in parallel (ohms)

\( X_s \) = Reactance in parallel (ohms)

CASE 2  This program is designed to parallel a circuit that is in series. The method is the leaning ladder method.

\[ R_p = R_s + \frac{X_s^2}{R_s} \]

\[ X_p = X_s + \frac{R_s^2}{X_s} \]

where:

\( R_p \) = Resistance to be paralleled (ohms)

\( X_s \) = reactance to be paralleled (ohms)

\( R_2 \) = Resistance in series (ohms)

\( X_2 \) = resistance in series (ohms)

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NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word **INSTRUCTION** will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.
OPERATING INSTRUCTIONS

EXAMPLE
Resistance = 25 (ohms)
Reactance = 50 (ohms)
Find RS, XS

1. Key **RESET**  **CLEAR**  **CR/LF**
   **LOAD**  **CR/LF**
2. Key **RUN**  **CR/LF**
3. **INSTRUCTION**
   **INPUT CASE NO.** (1 OR 2)
   Case 1, finds a series circuit
   Case 2, finds a parallel circuit
4. Key **CASE NO.**  **CR/LF**
   4. Key **1**  **CR/LF**
5. **INSTRUCTION**
   **RESISTANCE?**
6. Key **RESISTANCE**  **CR/LF**
   6. Key **2 5**  **CR/LF**
7. **INSTRUCTION**
   **REACTANCE?**
8. Key **REACTANCE**  **CR/LF**
   8. Key **5 0**  **CR/LF**
   **If Case no. 1, go to Step 9.**
   **If Case no. 2, go to Step 11**
9. Read
   **RS = 20**
   **RX = 10**
10. Go to Step 12
11. Read
   **RP =**
   **XP =**
12. **INSTRUCTION**
    **MORE INPUT?** (1 = YES, 0 = NO)
13. Key **0** or **1**  **CR/LF**
    13. Key **0**  **CR/LF**
    **If you keyed 1**  **CR/LF**, go to Step 3. Otherwise, program ends.
PROGRAM ABSTRACT

This program computes the characteristic generator resistance and the source emf voltage of an efficient rf switched amplifier whose output power swings with mismatch.

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PROGRAM DESCRIPTION

This program computes the characteristic generator resistance and the source emf voltage of an efficient rf switched amplifier whose output power swings with mismatch.

Generator Resistance

\[
R_0 = Z_0 \frac{1 - \frac{R_2}{Z_0} \left( \frac{P_f_{\text{max}}}{P_f_{\text{min}}} \right)^{1/2}}{\left( \frac{P_f_{\text{max}}}{P_f_{\text{min}}} \right)^{1/2} - \frac{R_2}{Z_0}}
\]

Source emf Voltage

\[
E = \frac{2 (R_0 + R_2)}{(Z_0 + R_2)} - \sqrt{Z_0 P_f_{\text{max}}}
\]

where:

- \( R_0 \) = Characteristic generator resistance (ohms)
- \( Z_0 \) = Characteristic impedance of transmission line (ohms)
- \( R_2 \) = Real load resistance (ohms)
- \( P_f_{\text{max}} \) = Maximum forward-going power (watts)
- \( P_f_{\text{min}} \) = Minimum forward-going power (watts)
- \( E \) = Source emf voltage (volts)

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.
OPERATING INSTRUCTIONS

1. Key RESET CLEAR CR/LF
   LOAD CR/LF

2. Key RUN CR/LF

3. INSTRUCTIONS

4. Key CHARA. IMPEDANCE CR/LF

5. INSTRUCTION

6. Key REAL LOAD RESISTANCE CR/LF

7. INSTRUCTION

8. Key MAX. FORWARD-GOING POWER CR/LF

9. INSTRUCTION

10. Key MIN. FORWARD-GOING POWER CR/LF

11. Read

12. INSTRUCTION

EXAMPLE

Characteristic Impedance of transmission line (ohms) = 50
Real load resistance (ohms) = 16.7
Max. forward-going power (watts) = 100
Min. forward-going power (watts) = 20

CHARA. IMPEDANCE OF TRANSMISSION LINE (OHMS)?

4. Key 5 0 CR/LF

REAL LOAD RESISTANCE (OHMS)?

6. Key 1 6 . 7 CR/LF

MAX. FORWARD-GOING POWER 'WATTS)?

8. Key 1 0 0 CR/LF

MIN. FORWARD-GOING POWER (WATTS)?

10. Key 2 0 CR/LF

CHARACTERISTIC GENERATOR RESISTANCE = 6.654685808016 OHMS
SOURCE EMF VOLTAGE = 49.51801111596 VOLTS

MORE INPUT? (1 = YES, 0 = NO)
If you have more input, go to Step 3. Otherwise program ends.
"ERLANG B" EQUATION

PROGRAM ABSTRACT

Computes the probability that exactly N equipments will be busy simultaneously when offered to Erlang's (Grade of Service).

<table>
<thead>
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<th>BLOCK</th>
<th>SAVE &quot;NAME&quot;</th>
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<tbody>
<tr>
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PROGRAM DESCRIPTION

In the administration of a telephone or telex exchange, it is common to estimate the load upon groups of equipments by reading Erlang meters associated with each grouping of equipments.

The purpose of such activities is to determine the grade of service given the number of equipments and the traffic offered. The "Erlang B" equation that is calculated is:

\[ P = \frac{T^N}{e^T} \frac{1}{N!} \]

where:

\[ T = \text{Traffic offered in Erlangs} \]
\[ N = \text{Number of equipments} \]
\[ P = \text{Probability that exactly } N \text{ equipments will be busy simultaneously when offered to Erlangs (Grade of Service)} \]

NOTE

Many operating instructions are presented via the CRT (display) or one of the output devices. When such instructions occur the word INSTRUCTION will appear on the left hand side of the operating instructions and what is displayed or typed will appear on the right hand side.
OPERATING INSTRUCTIONS

1. Key **RESET**  **CLEAR**  **CR/LF**
   **LOAD**  **CR/LF**
2. Key **RUN**  **CR/LF**
3. **INSTRUCTION**
4. Key **TRAFFIC**  **CR/LF**
5. **INSTRUCTION**
6. Key No. of Equipments  **CR/LF**
7. Read:
8. **INSTRUCTION**
9. Key 0  **CR/LF**
   or
   Key 1  **CR/LF**

If you have more input, go to Step 3. Otherwise program ends.

EXAMPLE

Traffic = 17.075 Erlangs # of equipment = 24.

TRAFFIC IN ERLANGS

4. Key 1 7 . 0 7 5  **CR.LF**

NO. OF EQUIPMENTS

6. Key 2 4  **CR/LF**

P = 2.33546384E-02

MORE INPUT (1 = YES, 0 = NO)

9. Key 0  **CR/LF**